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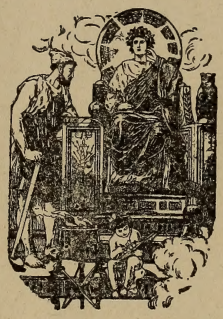

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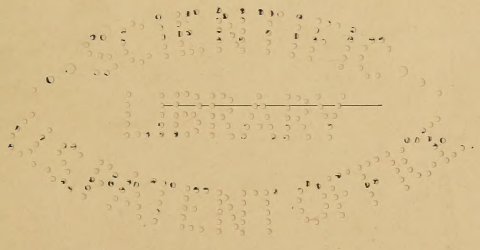

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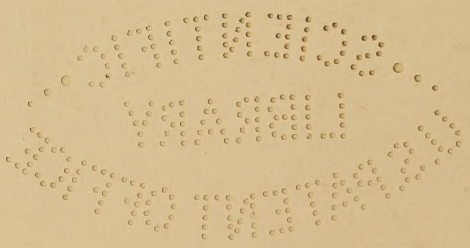

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HISTORICAL REVIEW OF THE DEVELOPMENT OF THE INTERNAL-COMBUSTION ENGINE

By Henry Harrison Suplee

VERY early in the history of mankind it was understood that heat had the effect of producing work by the expansion which it caused in the substances upon which it acted. Probably the earliest record which we have of such action appears in the *Pneumatica* and *Spiritalia* of Hero of Alexandria, in which we find descriptions of the action of heat on air and water, and the manner in which this was applied by the priests of the time, about 130 B. C., to the production of phenomena which appeared to the common multitude to partake of supernatural powers. It is altogether probable that the ancients possessed a greater knowledge of the effects of heat than has reached us in any permanent records, and since such knowledge was practically lost during the ages of darkness which followed the downfall of the Roman empire, it is possible to trace the history of modern prime movers only to a period at which the light of modern thought began to illuminate the doings of mankind.

It is probable that one of the earliest machines in which the action of heat was converted directly into motive power was not only a gas engine, but a gas turbine. The so-called "smoke-jack," used in mediæval times to operate the turnspit before the fire, consisted of a sort of screw propeller wheel placed in the chimney and caused to revolve by the action of the ascending gases, the motion being transmitted by gearing and belts to the spit which carried the roast before the fire. There are numerous instances of such devices, illustrations being given in the sketch books of the great artist-engineer, Leonardo da Vinci, as well as in other works of the time, and the smoke-jack may be considered as much a prototype of the gas turbine as the machines of Hero and of Branca have to be considered predecessors of the steam turbine.

It has been claimed that fire artillery is entitled to be considered as an elementary form of the gas engine; but this is to be doubted, especially if we accept the definition of a machine, as given by Reuleaux, as "a combination of resistant bodies so arranged that by their means the mechanical forces of Nature can be compelled to do work, accompanied by certain determinate motions."

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In the case of the gun, the force certainly does produce a motion; but it can hardly be considered as determinate, at least in the sense in which the movements of a practical machine are so considered. At the same time there is little doubt that the first combustion motor, in the precise sense of the term, was that made by Huyghens, in 1680, and by Papin, in 1690, by means of the explosion of gunpowder in a closed vessel. These experiments, however, did not involve the use of the force developed by the explosion of the powder, but utilized instead the vacuum following the combustion. A small quantity of powder was exploded in a large vessel filled with air, the force of the explosion expelling a portion of the air through check valves, and leaving, after cooling, a partial vacuum. This vacuum was then utilized to cause the pressure of the atmosphere to press down a piston, much in the same manner as in the early atmospheric steam engines.

About one hundred years later, in 1791, a British patent was taken out by John Barber for a motor which seems like an anticipation of the present attempts to make a gas turbine. He used gas, produced by distilling wood, coal, oil, or other hydrocarbon in a retort, the cool gas being delivered, with the proper amount of air, into an explosion or combustion chamber, where ignition took place, and the products of combustion were discharged against the buckets of a turbine wheel. Barber went even so far as to inject water into the combustion chamber to reduce the temperature, the mixed steam and gases acting upon the wheel. There appears here to have been an anticipation of most of the elements of the gas turbine, but as the principles of turbine construction were not clearly known at the time, the machine was doubtless of very low efficiency. This seems, however, to have been the first plan involving combustion at constant pressure.

Leaving these early engines as impracticable, the first real combustion motor, in the modern sense of the term, seems to have been that of Robert Street, who, in 1794, took out a British patent for an engine in which a piston was moved in a cylinder by the pressure of the gases generated by the combustion of spirits of turpentine. In Street's engine the bottom of the cylinder was heated by a fire beneath, and with the piston at the lowest point of the stroke, a few drops of turpentine or other inflammable liquid were injected and vaporized. The upward movement of the piston drew in some air, and also sucked in a flame, which ignited the inflammable mixture, and the explosion drove the piston to the top of the stroke. Here we find the use of the suction of the piston to draw in the charge, the use of an external flame for ignition, and other details included in more recent machines; but the constructive methods of the time were inadequate to the realization of the ideas of the inventor.

The next instance of a combustion engine was that patented by Lebon, in 1799 and 1801, for the utilization of illuminating gas, then but recently introduced, for the production of power. This remarkable man seems to have anticipated nearly all the elements which go to make up the modern gas engine. He admitted gas and "sufficient air to make it ignite" into the cylinder, the gas and air being compressed separately in two pumps before entering the motor cylinder, and the ignition being effected by an electric spark. Lebon thus designed a two-cycle engine, with compression, and with many details which have only recently come into general use, and it is probable that his early death alone prevented the development of the internal-combustion engine much earlier than actually was the case. It is true that the manufacture of illuminating gas was then in its infancy, and that the production of the electric spark

was also possible only in a very primitive manner; but the principles of the most modern types of gas engine were included in the plans of Lebon, who must be considered as an important pioneer very early in the field.

In 1807 a French patent was taken out by De Rivaz which contained some ingenious ideas. A vertical cylinder was fitted with two pistons, the upper one being the power piston, and the lower one being provided with a valve opening outward and forming the charging device. The upper piston being at the bottom of its stroke and the lower one in its highest position, and a communication with the gas reservoir and with the external air being in the small space between the two pistons, the lower piston was moved downward, thus drawing the charge of gas and air into the space between the two. The charge thus being ignited by an electric spark, the upper or power piston was forced upward. This sequence of events being repeated every revolution, a continuous action was obtained. De Rivaz used hydrogen gas, and also what he termed "vegetable hydrogen," the latter being probably a hydrocarbon distillate. It is especially interesting to note that De Rivaz used his engine to propel a vehicle.

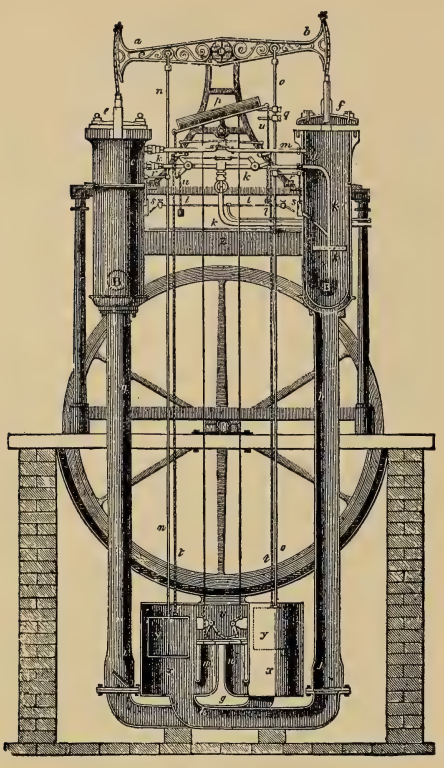
That the correct principles upon which an internal-combustion motor should be built were beginning to be understood at the commencement of the nineteenth century seems very evident. The proposed engines of Morey, of Montgery, Cheverton and others show that it was realized that the steam engine contained certain inherent defects which need not exist in an engine in which the fluid was a permanent gas, or at least a gas which did not change its state within the working range of temperature. Cheverton, who experimented in 1826 with the problem, stated the case very clearly, and the situation could hardly be expressed more definitely to-day than in his words, as follows:—

"It has long been a desideratum in practical mechanics to possess a power engine which shall be ready for use at any time, capable of being put in motion without any extra consumption of means, and without a loss of time in its preparation. These qualities would make it applicable in cases where but a small power is

SAMUEL BROWN
INVENTOR OF THE GAS VACUUM ENGINE. 1823

wanted, and only occasionally required. They are so numerous, and the consequent saving of human strength would be so great, that the advantages accruing to society would be immense, if even the current expense were much greater than that of steam. Such an engine should also be actuated by a force so concentrated and so compendiously appropriated as to occupy but little space, and be but of little weight, by which it would become applicable to locomotive purposes."

Mr. Cheverton, like Brunel, Torrens and others, endeavored to use liquefied carbonic acid, to which attention has been recently drawn by the experiments of Sir Humphrey Davy, and he failed to produce a



BROWN'S GAS VACUUM ENGINE. 1823

practical machine; but there is no doubt that he and others at that time realized fully the advantages to be secured from a gas engine. The method, however, which appealed to the inventors of that time who endeavored to use gas was the production of a vacuum by the explosion of a mixture of gas and air and subsequent contraction of the products of combustion.

One of the first to attempt this method of obtaining power from gas combustion was the Rev. Mr. Cecil, whose paper, presented before the Cambridge Philosophical Society, in 1820, accompanied by a model, showed very clearly the possibility of constructing a machine on this principle. It does not appear that a working engine was ever built by Mr. Cecil, but he was closely followed in this line of invention by Samuel Brown, who undoubtedly did produce a working gas-vacuum engine. Brown's patents of 1823 and 1825 describe the engine very fully, and with the accompanying illustration they will enable its operation to be clearly understood.

The two cylinders *c* and *d* are the vessels in which the vacuum is to be effected; from these descend the pipes *g i g* and *h j h* leading into the lower cylinders *x x,* from which the water rises along those pipes to fill the vacuum cylinders alternately. The water thus supplied is discharged through the pipes *B* into the tank or trough *z,* whence it falls upon the overshot water-wheel, and by the rotary motion thus produced gives power to such machinery as may be connected to it. The water runs from the wheel, along a case surrounding the lower half, into a reservoir *v,* from which the lower cylinders *x x* are alternately supplied.

In order to produce the vacuum, the necessary quantity of gas is supplied to the cylinders by means of the pipe *k k k,* to be conveniently attached to a gasometer. The gas also passes along the small pipe *l l* (communicating likewise with the gasometer), and being lighted at both ends of that pipe, is constantly burning for the purpose of igniting the gas within the cylinders.

The water in the reservoir *v,* passing down one of the pipes *w* into one of the lower cylinders *x,* causes the float *y* in that cylinder to rise, and, pushing up the rod *o,* raises the end *b* of the beam, which, of course, draws up with it the cap *f,* and forces down the cap *e* of the other cylinder *c.*

The gas being admitted along the pipe *k* to the flame from the pipe *l* is now freely communicated to the gas in the cylinder through the orifice by the opening of the sliding valve *s,* which is raised by the arm *r,* lifted by the rod *o,* by means of the beam.

To produce the intermitting action of each cylinder some subordinate machinery is put in operation, by chains and rods attached to a glass or

iron vessel *p* partly filled with mercury, and, turning upon a pivot, each end receives its movements of elevation and depression from the rise and fall of the projecting arms *q*, by the action of the beam above, the mercury being furnished for the purpose of regulating the supply of the gas into the cylinders and the movement of the slide in the trough *v*. By the action thus communicated the water from the reservoir flows down the pipe *w* into the vessel *x*, and produces the elevation of the float *y* and the rod *n*, and raises the cap *e* by the ascent of the beam at *a*.

The motion thus caused in this part of the machinery, operating upon its duplicate parts on the other side, of course produces by its action a corresponding movement; and the slider in the trough *v*, moved by the action of the mercurial tube *p*, being removed from its position, allows the water to fall into the other pipe *w*, and, as it ascends, suffers the float *y* to descend, and rising into the main cylinder, thus lifts again the beam at *b* and its connections, and forces down the cap *e* on the top of the other cylinder.

After the vacuum is effected in the cylinders the air must be admitted, to allow the water to be discharged and the caps to be raised; this is accomplished by means of a sliding valve in the air pipe *m m*, acted upon by chains *t t*, attached to the floats in the reservoir, and, as motion is given to them, the valve is made to slide backwards and forwards, so as to allow of the free admission of atmospheric air.

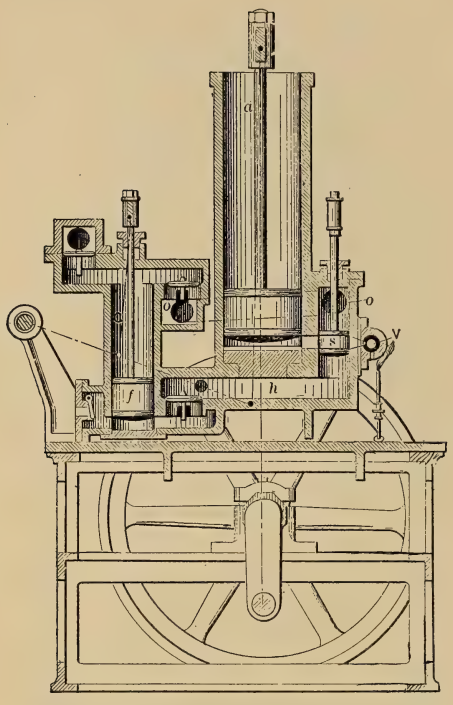
Chains *u u*, with suspended weights, open the cocks in the pipe *k k*, and produce the alternate flow of the gas and regulate and modify its supply.

In the pipes *g i g* and *h j h* are clacks to prevent the return of the water when the air is admitted into the cylinders.

When pistons are worked, the vacuum is effected (in the manner above described) under the piston, which is then pressed down by the weight of the atmosphere, and as an engine of that description is worked with two cylinders and pistons, the vacuum being produced in each cylinder alternately, the fall of one piston raises the other, and, being alternately pressed down, the piston rods give motion to the crank and flywheel. The air is admitted through large valves in the piston and through orifices in the cylinders. An engine may be worked with one piston, the vacuum being produced in two cylinders (as in the water engine), from which a pipe communicates with a third cylinder, in which the piston works, and into which the air is admitted alternately under and over the piston, while the vacuum extends to its opposite sides. By this contrivance a much greater rapidity of motion may be given to the piston, if required.

It was attempted to bring the Brown engine into commercial service by the formation of the "Canal Gas Engine Company," and an engine of this type was constructed and placed in a boat which was propelled on the Thames from Blackfriars bridge at the rate of seven to eight miles an hour. Tests made before the Lords of the Admiralty showed the machine to be practical, so far as actual operation was concerned; but the cost of gas rendered the commercial introduction of the engine impossible.

Following after Brown, we find, in the explosive pressure engine of W. L. Wright, in 1833, the introduction of one of the essential elements in the modern gas engine, the water-jacket, for the prevention of such excessive heating of the cylinder as might injure the working parts and destroy the lubrication. Five years afterwards we come to the very practical engine of Barnett, in which we observe the use of compression in the working cylinder, one of the essential elements in the present engines. Barnett also devised a simple and effective gas-flame system of ignition, forming the predecessor of



BARNETT'S COMPRESSION ENGINE. 1838

the method used with success in the early engines of Otto.

The engine of Barnett shown in the illustration employed a separate compression pump. The working cylinder is shown at *a*, while *c* is the air pump, and behind it is the gas pump. The so-called "loading chamber" is at *h*, and into this the charge of air and gas is forced by the two pumps. At *v* is the ignition valve, shown in detail in the upper left corner, and when the main piston is on the dead centre the piston valve *s* descends and throws the loading chamber and working cylinder into communication with each other and with the igniting flame, and the explosion occurs. On the return stroke the working cylinder is put into communication with the upper portion of the air pump cylinder, and the burnt gases are thus drawn out.

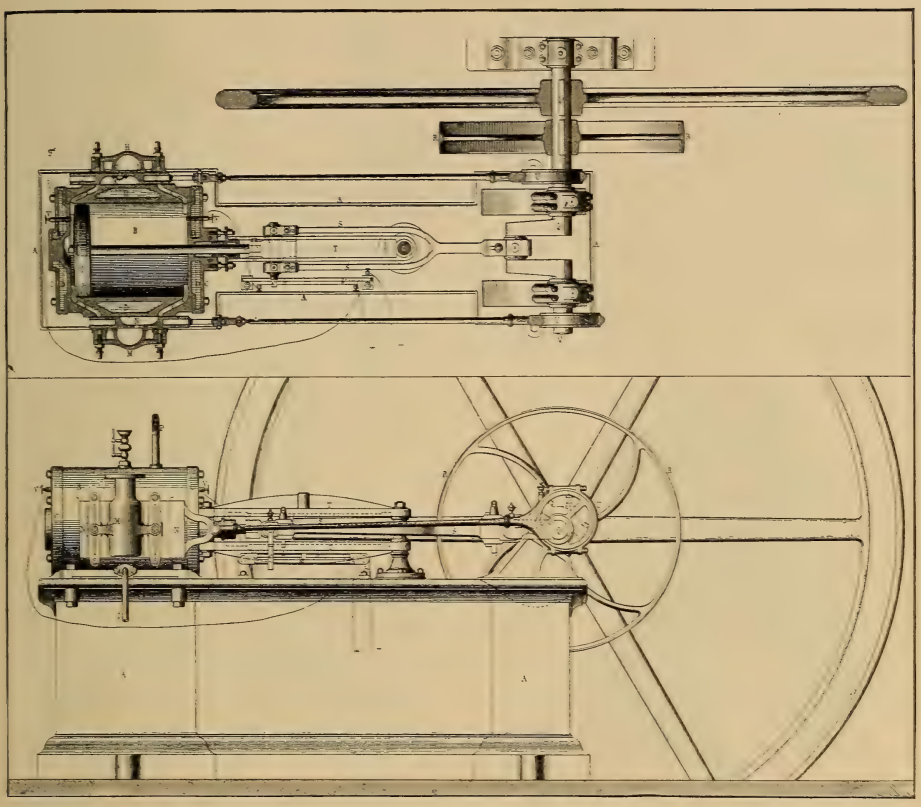
The American patent of Drake is of interest because it contains mention of the use of an incandescent tube for the purpose of igniting the charge, a plan also suggested by Siemens, and practically applied later by Daimler. Both Barnett and Drake stated that their engines could be operated with the vapour of hydrocarbon liquids, thus showing that the field of the internal-combustion engine was being extended beyond the limitations of gaseous fuel.

The idea of a gas-vacuum engine continued to appeal to inventors, and in 1854 two Italian engineers, Barsanti and Matteucci, designed an engine in which the explosive mixture was to be ignited under a free piston in an open-top vertical cylinder, the piston to be pressed down by the weight of the atmosphere after the explosion, and the reciprocating motion thus obtained to be transmitted to a shaft

J. J. ETIENNE LENOIR
INVENTOR OF THE FIRST COMMERCIAL GAS ENGINE

by means of a ratchet and pawl arrangement. It does not appear that this engine was ever built, but this construction appears again in the engine of Otto and Langen, of which mention will be made hereafter.

We come now to the real beginning of practical gas engine construction with the advent of the Lenoir engine, for which the first patent was taken out in January, 1860. J. J. Etienne Lenoir, by birth a Belgian, spent his life mainly in Paris, having there learned the trade of an enameler and electrotyper, or rather electro-plater, and his connec-



THE LENOIR GAS ENGINE OF 1860; FROM CONTEMPORARY PUBLICATIONS. DOUBLE ACTION; WATER JACKETING; ELECTRIC IGNITION, ETC.; THE FIRST COMMERCIAL GAS ENGINE

tion with this department of electricity led him to become interested in mechanical devices, of which the most important was the gas engine. Lenoir was fortunate in having the construction of his first machines placed in the hands of M. Hippolyte Marinoni, a well-known manufacturer of first-class machinery, so that his engines from the first were well designed and built. An examination of the illustrations, reproduced from publications of the time, show that the general arrangement of French steam engines was closely followed, and give a clear idea of this, the first commercial gas engine.

The immediate success of the Lenoir engine showed that there was a real demand for such a machine. It is stated that about four hundred engines were made during the five years succeeding the patent in France alone, and a hundred in England.

Certain defects naturally appeared in the practical experience with the Lenoir engine, the principal one being in connection with the lubrication of the cylinder and valves. It must be remembered that this was a double-acting machine, with closed cylinder and stuffing box, a type which even now requires most careful construction and thorough cooling, not only of the cylinder, but of the piston, rods and valves, to insure reliability in operation. Nevertheless, the Lenoir engine remained on the market until it was superseded by later and more efficient types, an ample testimony to its practicability.

Lenoir, in addition to his design of a stationary engine, constructed, in 1863, a vehicle propelled by his mo-

tor, and this machine, undoubtedly the first operative automobile propelled by a combustion engine, made a trip from Paris to Joinville-le-Pont and return in three hours, although the power of the engine was but one horse-power. The principal difficulty with this machine was the weight of the motor and the volume of cooling water to be carried. The fuel was a liquid hydrocarbon or essence. A two horse-power Lenoir engine was also placed in a boat,

BEAU DE ROCHAS
ORIGINATOR OF THE FOUR-STROKE CYCLE FOR GAS ENGINES

which ran between Paris and Charenton several times a week for two years.

The real obstacle to the extended use of a non-compression engine, such as the Lenoir, was the large gas consumption, this exceeding 100 cubic feet per horse-power per hour with city illuminating gas. Except in cases where steam power was not available, this was too high for general manufacturing purposes.

A rival engine to that of Lenoir appeared in Paris in 1862, that of Hugon, which differed mainly from the Lenoir engine in that it employed flame ignition instead of electricity, and used a spray of water, injected into the cylinder at each end of the stroke, in addition to the water-jacket, to aid in cooling the cylinder. The high consumption of gas in this engine, about 85 cubic feet of illuminating gas per horse-power per hour, prevented its extensive introduction. The real reason for this high consumption was not fully perceived at the time, but in 1862 there was taken out in France a patent by Beau de Rochas, the real purport of which did not then appear, but which actually formed the foundation of all the immense progress which has been made since that time. Beau de Rochas insisted upon the importance of realizing the highest pressure at the beginning of the expansion, and in his patent he laid down the sequence of events which must form the operative cycle, as follows:—

1.—Drawing in the charge of gas and air;

2.—Compression of the gas and air;

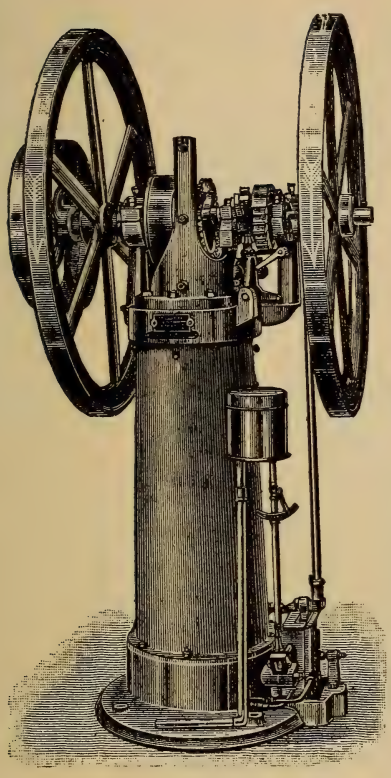
3.—Ignition at the dead point, with subsequent explosion and expansion;

4.—Discharge of the products of combustion from the cylinder.

It is not generally remembered that in addition to enunciating the correct cycle for the operation of a practical and economical gas engine, Beau de Rochas also emphasized the practicability of employing the heat of compression for the ignition.

This is a method which has been applied practically in but a few machines, notably in the Diesel motor; but it is interesting to note that its possibility was perceived so early as 1862. It does not appear that M. Beau de Rochas ever made a commercial engine in accordance with his patent, but he lived for thirty years afterwards, surviving until 1892, and having witnessed the practical utilization of his cycle by Otto and his followers. He received awards from the Académie des Sciences and from the Société d'Encouragement, in recognition of his work, and his claims to recognition are now fully conceded.

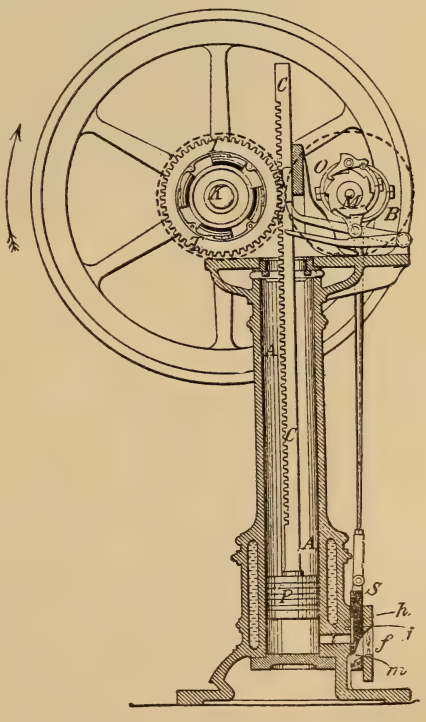
In 1866 Messrs. Otto and Langen produced a vacuum gas engine on lines similar to those already proposed by Barsanti and Matteucci,



THE OTTO AND LANGEN ENGINE OF 1866

this being a single-acting atmospheric engine in which the piston was driven upwards in a tall, vertical cylinder by the explosion of a charge of gas and air beneath, and then forced down by atmospheric pressure by reason of the vacuum following the explosion. The piston rod was formed as a rack, engaging with a pinion on the fly-wheel shaft, and a clutch between the pinion and the shaft on the down stroke caused rotation of the shaft, the upward or explosion stroke being free. The general arrangement is clearly shown in the illustration, which gives a vertical section of the machine as it was exhibited at Paris in 1867. An important element in the operative success of this engine appeared in the design of the friction clutch, it being necessary that this should be entirely free during the entire upward movement of the piston, but engage instantly upon the reversal. This engine had flame ignition, and, while noisy and somewhat unsteady in its action, it came into commercial use for a number of purposes requiring moderate power. In this engine we meet with the so-called "hit-or-miss" system of speed regulation, about the only system which could be practically applied to a machine of this kind. Tests made by Tresca upon a half horse-power engine of this type at the Paris Exposition of 1867 showed a gas consumption of 44 cubic feet per horse-power per hour, or less than one-half that of the Lenoir engine.

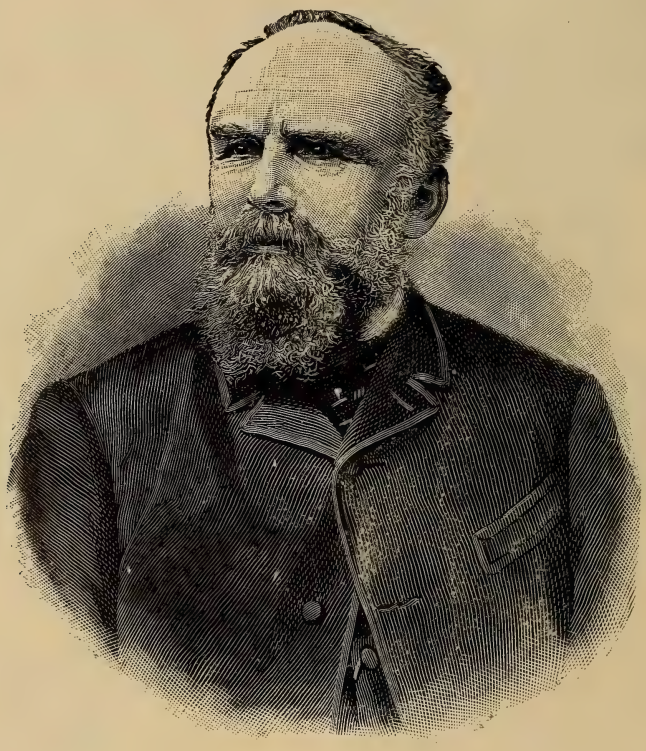
We now come to an engine which, while introduced on a commercial scale, did not make the progress which its merits demanded, and which was, in fact, far ahead of its time, that introduced by Brayton in 1873. Brayton, understanding the necessity of compression, also appreciated the possibilities of the so-called "constant-pressure" cycle, as op-



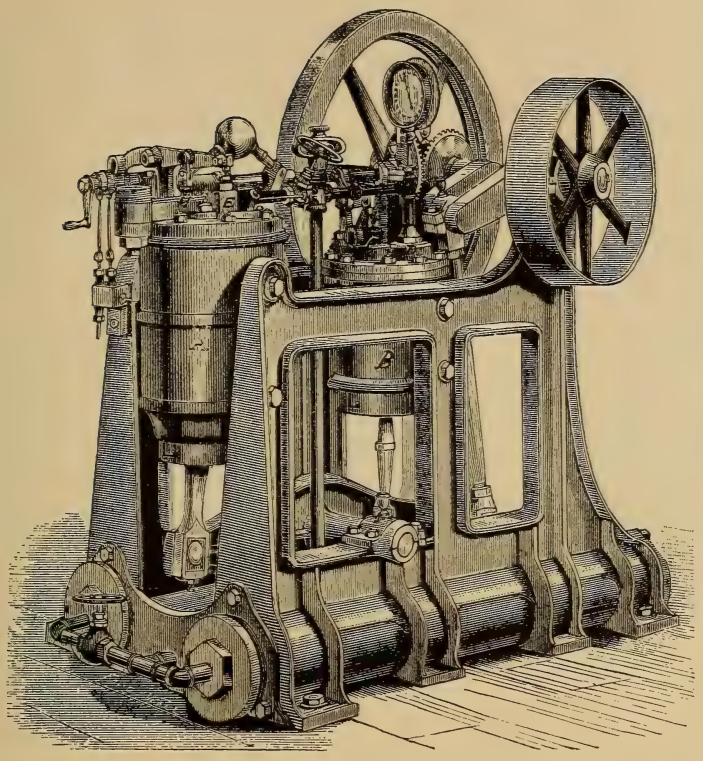
SECTION OF THE OTTO AND LANGEN ENGINE

posed to that of constant volume. Upon this principle he constructed a true combustion motor, in which the gases burned in the cylinder instead of exploding. Using a single-acting cylinder, he effected a power stroke at every revolution of the crank, the compression being furnished by a separate compression cylinder, not for the corresponding stroke, but to maintain a supply of compressed air in a reservoir from which it might be drawn as wanted.

The principle upon which the Brayton engine operated may best be described by an experiment which Brayton himself performed before the Franklin Institute for the purpose. A spherical brass vessel, made in halves, so that it could be taken apart, was filled with an absorbent material, such as felt, this being saturated with kerosene or gasoline, and closed. On one side of this globe was fitted a short nozzle, and on the other a small pipe and stop-cock connected with a reservoir of compressed air. By opening the stop-cock slightly, a small flow of air was permitted through the charge of hydrocarbon, and the carburetted air, escaping from the opposite nozzle, was ignited, and burned with a small, quiet flame. When, however, the stop-cock was opened widely, a great rush of flame, several feet long and of large volume, was emitted from the nozzle, while upon turning down the air pressure the flame instantly responded by falling to its original small size. Such a device, in the Brayton engine, was fitted to the closed end of the cylinder, and the minimum flow of air was always passing through, so that the flame never went out. When the piston



EUGEN LANGEN
ASSOCIATED WITH DR. N. A. OTTO IN THE DEVELOPMENT OF THE OTTO AND LANGEN GAS ENGINES

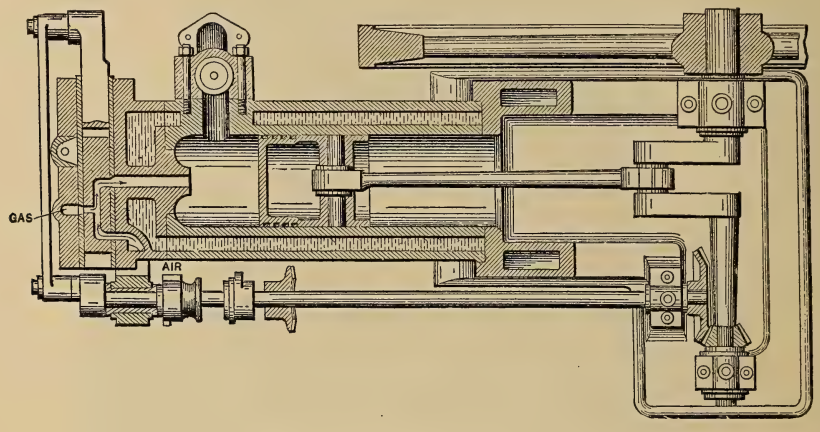


THE BRAYTON COMBUSTION ENGINE. 1873

was at its inner end of the stroke the air was suddenly turned on full and the cylinder filled with the flame of burning hydrocarbon. When the flame was turned down, the heated air and gases continued to expand, and on the return stroke, the exhaust valve being open, the burned gases were discharged, the flame continuing to burn at its smallest size, maintained by the supply of fresh air behind it. In the engine as actually constructed, the inverted beam type was adopted, as shown in the illustration. The cylindrical portions of the base formed the air reservoir, supplied by the air pump *B*, the working cylinder being at *A*. The engine included ingenious details for supplying the fuel by a small pump and for regulating the admission of air at the proper moment. Indicator cards showed that a true combustion at constant pressure was maintained in the cylinder, with expansion from the moment the flame was turned down, the diagram being similar to that of an automatic steam engine, and altogether free from any indication of an explosive action. A pressure of 60 pounds was maintained in the air reservoir, this giving an initial pressure of 48 pounds in the motor cylinder. The early death of Brayton was doubtless the cause of the neglect of this important engine, and its merits have since been recognized very recently in technical discussions.

Messrs. Otto and Langen continued to attempt to improve the action of their vacuum gas engine, but without much success, and in 1878, having established the works which have since become the famous Gas-Motoren Fabrik at Deutz, opposite Cologne, on the Rhine, they brought out an entirely new machine, based

on the cycle of Beau de Rochas, abandoning altogether the vacuum machine. In distinction from the noisy older engine, the new machine was called the Otto "silent" gas engine, and its presentation at the Paris Exposition of 1878 formed the commencement of the modern era of the internal-combustion engine, as a practical commercial machine, destined to compete with the steam engine in the magnitude and variety of its applications, and far surpassing it in efficiency in the conversion of heat into work.



THE OTTO GAS ENGINE OF 1878

Since a number of gas engines, constructed upon the same general principles as the Otto engine of 1876, are illustrated elsewhere in this issue, it will be necessary here only to describe the original Otto engine, the machine upon which practically all the commercial four-cycle engines of to-day are based.

The original Otto engine was horizontal, with single cylinder, the crank end of the cylinder being open, and the connecting-rod working upon a wrist pin fitted into the hollow trunk piston, thus dispensing with any crosshead or other arrangement of guides. The cylinder was made with such a clearance space between the head and the inner position of the piston as to provide for the degree of compression of the cylinder contents as was then thought necessary, this clearance in the early engines being about four-tenths of the working volume. The engine was thus arranged to operate exactly on the cycle proposed by Beau de Rochas, drawing in the charge of gas and air on the first outward stroke of the piston, compressing this charge into the clearance space on the return stroke. Ignition then taking place just as the inner dead centre was passed, caused the explosion and power stroke, followed by the fourth portion of the cycle, the return stroke driving the products of combustion, burnt gases, etc., out of the exhaust valve. Since the movement of the piston through three of the four strokes absorbed work, and only one stroke in every two revolutions was a power-generating stroke, a heavy fly-wheel of proportionately large diameter was found necessary to insure the storage of sufficient energy to effect the compression without materially affecting the speed of rotation.

Since the various movements of the valves, etc., repeated themselves after every second revolution only, it was necessary to arrange a valve shaft along the side of the engine driven from the crankshaft by a pair of bevel gears having the ratio of two to one, so that this shaft made one revolution to every two of the main crankshaft. From this valve

Courtesy of Macmillan & Co.

DR. J. P. JOULE
INVESTIGATOR OF THE MECHANICAL THEORY OF HEAT AND HEAT MOTORS

shaft the admission and exhaust valves, as well as the slide which controlled the ignition, were then operated by direct connection.

There were a number of details necessary to render this engine a commercial and reliable machine, and it was by reason of the skilful solution of these, and because of the excellent and substantial construction of the engine that the Otto engine of 1878 at once took the field and held it until the expiration of the fundamental patents opened it to every one.

An important element in the operation of the engine was the construction of the igniter. The use of flame ignition had been suggested by several earlier inventors, but it required much ingenuity to put it into practical and reliable operation. In the Otto engine this was effected by the device of a slide containing a chamber which received a small charge of gas from a special pipe, this charge being ignited by passing by an opening containing a free burner, and then passing on with its little burning charge to the port in the end of the cylinder to ignite the compressed charge. The exhaust valve was operated by a cam upon the valve shaft already mentioned, and the ad-

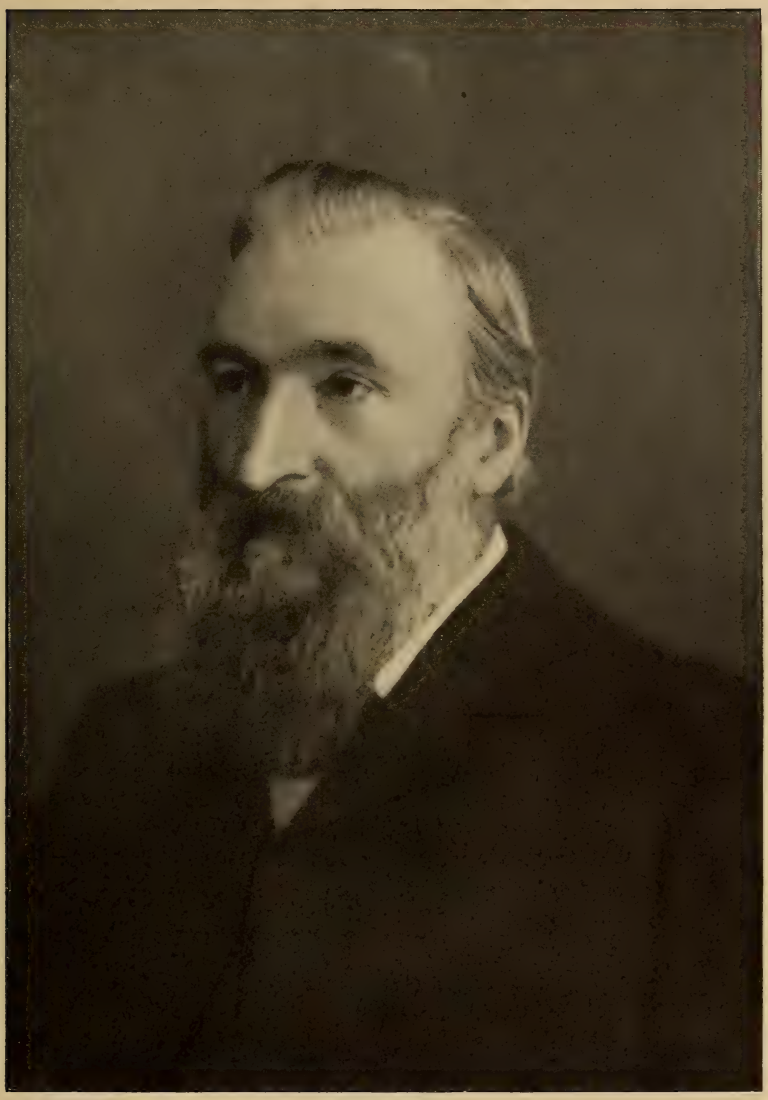
mission of air and gas took place through openings in the slide. The slide itself moved horizontally across the back end of the cylinder, being operated by a small crank on the end of the valve shaft.

The great advance which was made by the introduction of the Otto engine is seen by the fact that with these early engines, using but a moderate compression, the consumption of illuminating gas fell to 20 cubic feet per indicated horse-power, as compared with 44 cubic feet in the older Otto and Langen engine, or more than 100 cubic feet with the engine of Lenoir.

Although the Otto engine began to be extensively used for small powers almost immediately after its introduction, being manufactured in Germany, France, England and America, attempts were soon made to improve upon it. The principal features to attract the attention of inventors was the possibility of obtaining a power impulse at every other stroke, instead of every fourth stroke, and this was attempted in a variety of ways. This seems like an easy problem; but we may here quote the opinion of a competent authority, Mr. Dugald Clerk, who himself produced one of the earliest successful two-cycle compression gas engines:—

"At first blush, it seems a very simple matter to make a compression gas engine to give an impulse for every revolution; this was the author's opinion when he commenced work upon gas engines using compression, in October, 1876. Since then he has had occasion to modify the opinion; the difficulties are very great; any engineer who doubts this will speedily be convinced upon making the attempt."

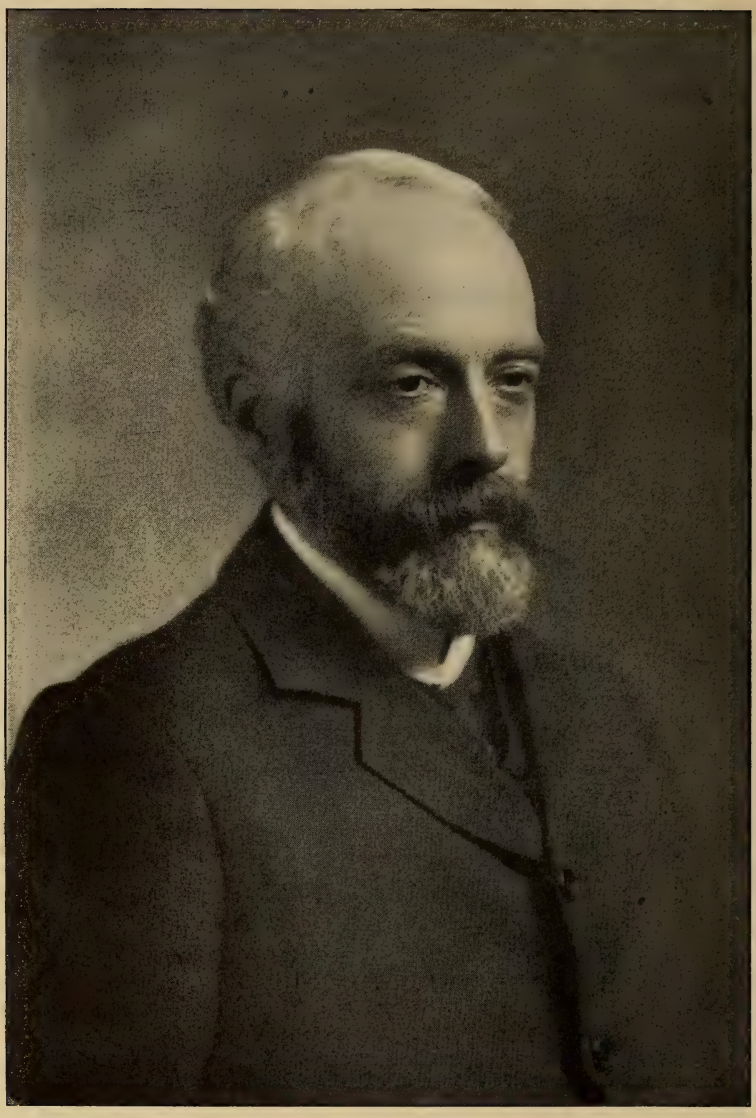
Mr. Clerk produced his two-cycle engine in 1880. The design resembled the Otto engine in external appearance, but it was in reality quite different. Besides the single-acting power cylinder, there was a separate cylinder, called the displacer, the piston in this cylinder being operated by a crank placed at right-angles to the main crank. The power-cylinder was made with exhaust ports near the outer end of the stroke, these ports being uncovered by the main piston as it approached its outer travel extremity. At this moment, while the main piston was moving at its slowest, the displacer piston was moving rapidly inward, and arranged to deliver fresh air and gas into the main cylinder, effectually driving out the burnt gases. The main piston then returned, covering the exhaust ports and compressing the air and gas ready for ignition at the inner end of the stroke. It will be seen that the action of the displacer piston replaced both the exhaust-stroke for the removal of the burnt gases and the suction-stroke for the entrance of the charge, leaving only the compression and the power strokes to be made by the main piston, and thus permitting these latter to take place at every revolution. The gas consumption of the Clerk engine was about the same as that of the Otto engine, but it succeeded in furnishing a power stroke for every revolution, although only by the addition of another cylinder for the displacer. Practically every plan which has been employed for attaining this object involves the necessity for another cylinder, or its equivalent. In many two-cycle engines the plan early employed by Robson is used, this being the closure of the crank end of the cylinder, using this portion of the main cylinder for displacing the burnt gases. In some later engines the entire front of the machine, including the crank and connecting-rod, is enclosed, so as to utilize the outward movement of the piston for the displacement and charging action. Most modern builders, however, have accepted the fact that the simplest mechanical and commercial method of obtaining a power stroke for every revolution of the crank is to duplicate the working parts, using two power cylinders, either side by



JAMES ATKINSON
INVENTOR OF THE DIFFERENTIAL GAS ENGINE

side or opposite, timing the explosions to occur alternately.

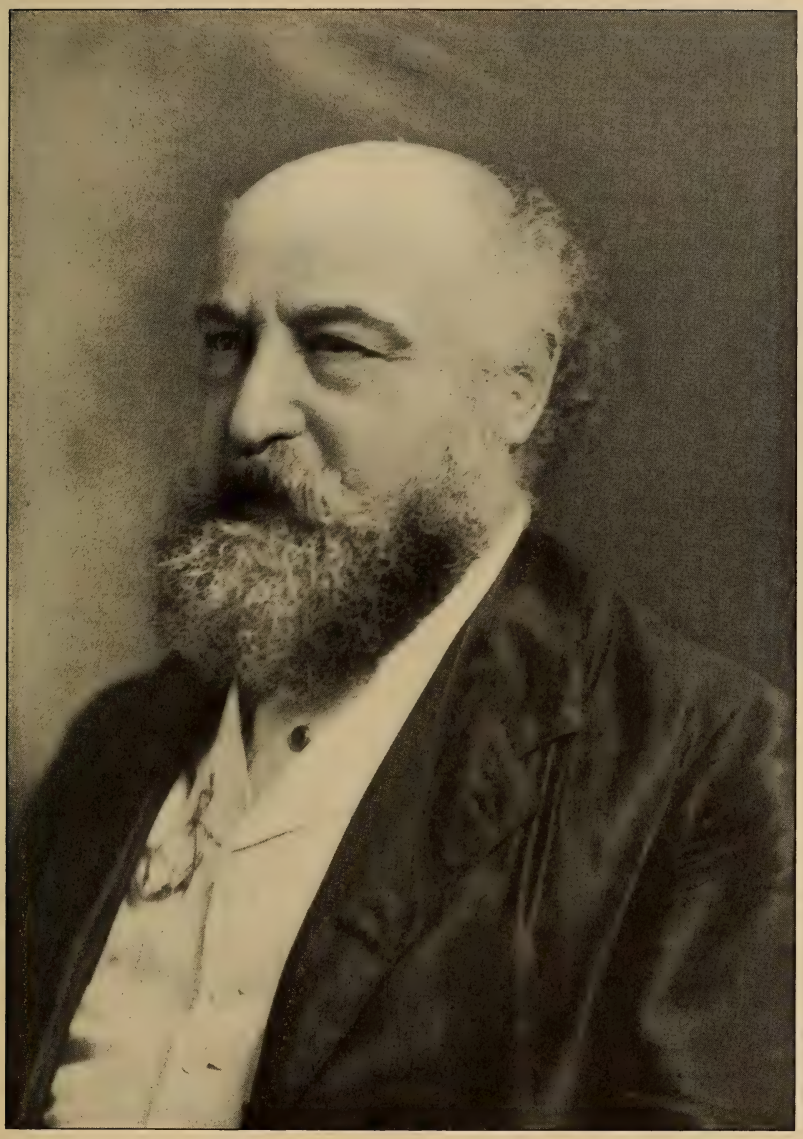
A very ingenious engine, first exhibited in 1885, was the so-called "differential" engine of Atkinson. This machine involved the action of two pistons in one cylinder, the cylinder, lying in the horizontal position, being open at both ends, the pistons entering at the opposite ends, and being connected to the shaft above by a combination of levers and rods, by which a differential movement of them was obtained. The pistons came close together at each end of the stroke and separated from and approached each other in the course of their travel, one separation drawing the charge in and the explosion occurring at the other separation of the pistons. At the approach of the pistons the compression was effected and again the approach caused the discharge of the



B. H. THWAITE
DISCOVERER OF THE APPLICABILITY OF BLAST FURNACE GASES FOR MOTIVE POWER IN GAS ENGINES

burnt gases. Mr. Atkinson afterwards designed another engine in which an ingenious differential action of levers between the piston and crank caused the single piston to make alternate strokes of different lengths, the piston travelling to the extreme end of the cylinder during the exhaust stroke, and thus clearing out completely all the burnt gases, while for the compression stroke the travel was shorter, leaving the predetermined clearance space for the compression of the charge.

The earlier engines depended for their speed regulation mainly upon the so-called "hit-or-miss" system, the centrifugal governor being so arranged that the supply of gas was cut off entirely if the speed increased, the supply not being resumed until the speed had fallen



DR. LUDWIG MOND
INVENTOR OF BY-PRODUCT GAS PROCESSES

slightly below the normal. This method was conducive to economy, since no gas whatever was consumed until the speed fell. In these engines the observer could notice that the motion of the fly-wheel was accelerated immediately after an explosion in the cylinder, when, if the load was light, there would be no explosion again for several revolutions, the momentum of the fly-wheel carrying the motion until a perceptible slowing down occurred, when the governor again permitted the gas valve to be opened and another power stroke to be made. Such a system, however, gave but an imperfect speed regulation, and it has since been very generally superseded by methods varying either the quantity of the

charge or its quality. Such success has been attained by these methods in the later engines that it is now practicable to use gas engines for the purpose of driving electrical alternators in parallel, requiring practical uniformity in rotative speed.

The original Otto patent expired in 1890, since which time the field has been entered by a great number of manufacturers in Germany, France, Belgium, Switzerland, England and the United States, and an examination of the pages of this number will show the extent to which the industry has been developed. Writing in 1898, Mr. Dugald Clerk commented upon the growth of the size of the gas engine from 1876, when 3 horse-power was considered a large size, to 1898, when the largest engine then built indicated 220 horse-power, and was considered an important and noteworthy machine. At that time Mr. Clerk made the following prediction, and in the light of what appears in the following pages, at a lapse of less than the ten years of which he speaks, the accuracy of his prophecy will be fully seen. Mr. Clerk said, in January, 1898:—"It is evident that the large gas engines of ten years hence will differ as much from the large gas engine of to-day as does the latter from the engine of 1886 or 1887. There can be little doubt that, in ten years, gas engines of 1,000 horse-power will be as common as engines of 100 horse-power are now."

The great obstacle to the introduction of the gas engine for general work and in large sizes lay in the cost of the fuel. So long as it was necessary to use the expensive gas prepared for the illumination of towns, the size and applicability of the gas engine was limited to service in which convenience, intermittent character and similar conditions overbalanced the actual cost of the fuel. The question early arose, therefore, as to the practicability of providing some cheaper gaseous fuel, so that the internal-combustion motor should be enabled to realize the advantage which its high thermal efficiency permitted. Siemens had already developed the fuel-gas producer for use in metallurgical operations, but this was at that time only available for large installations, and it was not at first believed that such a lean gas could be effectively used in the gas engine.

Producer gas, as the gas made in the Siemens apparatus was called, was made by the incomplete combustion of the fuel to carbon monoxide, the resulting gas consisting mainly of this gas and inert nitrogen. When the vapour of water is passed through an incandescent bed of coal the water is decomposed, the hydrogen remaining free and the oxygen combining with the carbon. The resulting product is termed water gas, and contains about equal parts of hydrogen and carbon monoxide by volume, together with small amounts of nitrogen, oxygen and carbon dioxide. If a small amount of steam is passed through the fuel bed of an ordinary gas producer there will be made a gas lying somewhere between the two, and termed semi-water gas. As long ago as 1878 Dowson designed a producer for the generation of a cheap gas for use in engines, this apparatus furnishing a mixed water gas, and having been very extensively employed. Producers of this type are generally made to be operated under pressure, the lower portion being closed by a water-seal and the air and steam delivered by a jet blower.

Benoit, a French engineer, in designing a producer for direct use with a gas engine, made use of the suction stroke of the engine itself to draw the air and vapour through the fuel, and this has led to the introduction of the convenient suction gas plants, now made by a number of engine builders for installations of moderate size. Both pressure and suction producers, when the gas is to be used for gas engines, are best operated with anthracite or coke,

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GOTTLIEB DAIMLER
THE FATHER OF THE AUTOMOBILE

since bituminous coal produces tarry and other vapours which are injurious to the action of the valves and working parts of the engine. Dr. Ludwig Mond, F. R. S., has developed a very important type of gas producer in which bituminous coal is used, and the valuable by-products are separated in the form of marketable products. A most important contribution to the development of the gas engine was made in 1894 by B. H. Thwaite, in applying the waste gases from blast furnaces and coke ovens to the operation of gas engines, a development which bids fair to revolutionize the power industry of certain localities. All of these developments will be found treated at length by specialists in other pages of this magazine.

A review of the development of the internal-combustion motor would not be complete without mention of the growth of the use of engines using liquid fuel. These, for the most part, operate in the same manner as gas engines, using some appliance for converting the liquid hydrocarbon into the gaseous form before deliv-

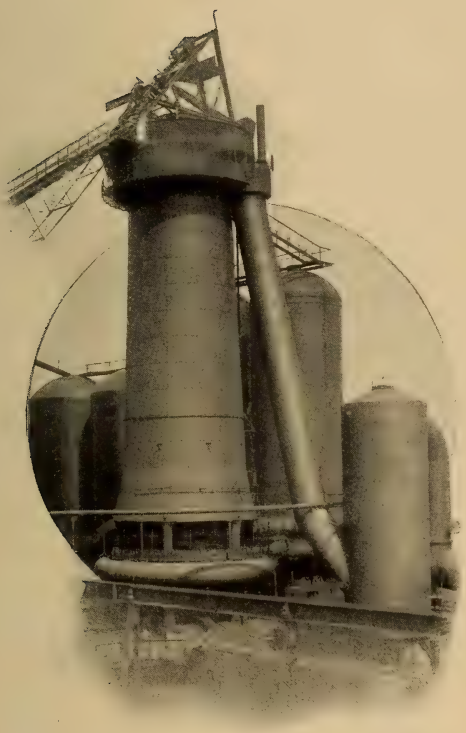
ering it into the cylinder. For such volatile liquids as benzine, essence, petrol and the various gasolines some form of carburetter is sufficient, the vapour and air making an explosive mixture suitable for use in the cylinder. The highest refinement in the design of motors for use with liquid fuel, however, is that of Diesel, in which the air is compressed separately to such a high pressure that its temperature is sufficient to ignite even the heaviest oils, the liquid fuel being injected into the cylinder at the beginning of the stroke, and no carburetter or special igniting device being employed. The excellent cycle used by Diesel, together with the high degree of compression, causes his engine to have a very high thermal efficiency, nearly 40 per cent. of the heat energy in the fuel being returned in indicated power.

Daimler improved the small combustion motor, especially in connection with the ignition apparatus, so that its speed could be greatly increased, thus rendering it possible to produce a high power with a machine of light weight. The result has been the development of the numerous varieties of small, powerful machines which have made the automobile industry possible, and which have led to the production of the modern motor boat. The possibility of weight reduction thus provided has led to the use of such motors in experimental work with dirigible balloons and aeroplanes.

We have seen that some of the earliest attempts to produce a combustion motor were along the lines of a gas turbine. Much attention has been given recently to the design and construction of such machines, and some very encouraging results obtained. The whole question, however, is dependent upon the successful combination of a number of difficult elements, and this type of combustion motor is still in the experimental stage.

THE BLAST FURNACE AS A CENTRE OF POWER PRODUCTION

By B. H. Thwaite



THE INCEPTION OF BLAST FURNACE GAS ENGINE POWER

AS far back as November, 1894, or some six months later than the date of the author's pioneer patent to harness the blast furnace to the gas engine (which resulted, as one of its incidents, in the creation of the large power internal combustion engines), the author contributed an article on the "Iron and Coal Trades Review," London, from which the following is an excerpt:

The utilization of the power for driving the mill machinery and for electric lighting in the works is another obvious advantage of this system. The serious waste of fuel in the generation and transmission of power in even the most modern of iron and steel works are well understood, and the annual saving by substituting gas motors driven with the blast-furnace gas for the present wasteful method may make all the difference in the balance sheets between profit and loss.

If the blast furnaces are not more than 5 miles away from the mill department, the energy loss in transmission may be considered practically negligible, because, with high-pressure electrical transmission, and with transformers, energy can be transmitted 100 miles, with not more than 30 per cent. loss. The power can also be utilized for colliery underground work, for pumping, drilling, and for haulage work.

Where the blast furnaces are entirely disconnected from the finished iron departments, the electric energy produced might be distributed to villages within a 20-mile radius for lighting and power purposes. This method could enable the power to be provided at such a price as to surpass gas-lighting distribution in economy of price, and in luminous efficiency, and the distribution would become a source of profit to the blast-furnace owner. The power that would be available could, if necessary, be supplemented by a battery of gas generators, which would always be useful auxiliaries in the event of blowing out the furnaces for repairs. Instead of flaring away at the open mouth of the furnace, the lighting power of these monuments of industrial enterprise would be electrically distributed to the houses in the surrounding towns and villages.

THE ORIGIN OF THE COUNTY ELECTRIC POWER PROPOSITIONS

This article, prophetic as it has proved, was merely a sequence to the author's proposition, made before the Manchester Association of Engineers in the year 1892, and repeated in the "Nineteenth Century," in favour of the central generation of power at the coal field for electrical transmission at high tension throughout the country; the original schemes in-

cluded one for Lancashire, one for Yorkshire and another for the distribution of power from the coal fields at Derbyshire to London. To-day we know that the metropolitan proposition is still waiting to be transformed into the dignity of *une fait accompli;* but both Lancashire and Yorkshire have their power schemes, which are, however, economically imperfect, because, unlike the author's scheme of 1892, which included gas power and by-product recovery generating stations, they are merely steam plants. Few of the most important counties in England are to-day without Parliamentary Acts that provide the basis for electric power distributing action, and there are signs that in the conversion of the Acts into actuality gas power, either from the waste gases of our blast furnaces or from producer gas generated from local coal, will be the source of the electrical transmission agency.

It must be clearly obvious, *mirabile visu,* that a new development of industry, which by its application will strengthen and stimulate the master manufacturing industry of a country, has deserved claims on our favourable consideration. If we were asked to name the master industry of Great Britain, or indeed of any of the great manufacturing nations, there could be little hesitation in replying: "That of iron and steel." Although it was said in an often quoted speech of one of England's famous prime ministers that the chemical trade formed the index of industrial prosperity, had this statesman, "Beaconsfield," known his England more intimately he would assuredly have selected iron as the index—an industry that, as the author forecasted thirteen years ago, is destined to fulfill a rôle as power provider that will make it not only the master industry, but one having almost, it may be said, patriarchal characteristics as well. Once we realize the power potentials of the huge volumes of gases that are flowing into the air from these furnaces, it is easy to imagine the extent of the benefits that might be secured if this power were electrically harnessed to the many industries within economic reach from our blast furnaces.

IRON CENTRES COINCIDENT WITH CENTRES OF MANUFACTURING INDUSTRY

It is an appropriate, if remarkable, fact that in England and Scotland at least many of our most important manufacturing centres are coincident with iron making centres. This truism is clearly brought out in the map, which shows the position, by the dots, of the well-established industries of some thirty years back, and the associated iron-making zones.

It might even be suggested that a divine influence shapes the direction of invention to secure an aggregation of benefits for the greatest service to man. It is obvious that an iron works far removed from the spheres of contemporary manufacturing activity would not be able to fulfill the rôle of power provider with such immediate advantage to any other industry as is that situated in the centres of existing industries.

Again, Nature herself being efficient in her great cycles of operation, there is no place for waste; it is the bounden duty of everyone to reduce this waste, and no waste is so inexcusable in the light of present science and its triumphs in practical work as that which not only deprives the country of a cheap service of power energy, but at the same time pollutes the air. Any excuse that might have held good has disappeared as a result of the present as nearly as practicable perfect stage in the evolution of generating and transmitting electrically - converted power energy over long and increasing distances.

The author's proposition of 1892, already referred to, involved the transmission of power over 112 miles at 20,000 volts. This pressure was considered to be a bold if not audacious figure to include, but we

POWER DISTRIBUTION FROM IRON-MAKING CENTRES

know that to-day such pressures must be considered within the most extreme limits of caution. But, as the map demonstrates, there will be no necessity to transmit the power energy beyond a circle drawn with a radius of 25 miles from any group of blast furnaces. But England is not alone in the advantage of possession of fields of power demand in the immediate environment of the blast furnace centres. Belgium, Germany, the United States, and, in a less degree, France, have their own

fields of demand, although none of these countries possesses an associated nearness to a seaboard, as does the iron industry of England. The first proposition which the author initiated in 1897 for the neighbourhood of Essen was based on the sources of demand in that district for any power that could be secured from the blast furnace company, and Herr Theissen has realized this fact, and there is to-day little power going to waste from the furnaces in the deservedly flourishing iron districts of Westphalia and Rhineland, and the dignity of dual utility to the German industry is already possessed by most of the important iron furnaces; and here it may be remarked that it would be more beneficial to France and her beautiful capital were the electric power for the city and the environment of thousands of ateliers drawn from the furnaces of Haute Marne rather than from the waters of the Rhone.

The great power output potential of the furnace gases polluting the atmosphere of Pittsburg would find a ready sale within the economic limits of distribution set by the modern methods of American electrical science.

A nation that persists in neglecting the calls of duty in the direction of securing economy and in reducing the pollution of the air which continues to contravene natural laws, deserves to be suppressed by other nations of greater wisdom.

These personal elements of a country that from sheer ignorance or prejudice delay or oppose the application of an economic invention are more deadly to national interests than any other conceivable enemy. Such prejudice and such sheer ignorance have ever been in active evidence in delaying reforms in the suppression of waste in England, but what England has lost Germany has gained, and so also has America. Although slow to realize the value of the reform, America is now, with characteristic enterprise, rapidly making good the lapse in her progressive history in the early indifference to the value of converting the gaseous residuals of her furnaces into a valuable power generating asset. It has been suggested that Paris should get its energy from the French blast furnaces, say at Haute Marne, rather than from the waterfalls of the Rhone. The suggestion naturally challenges a comparison between the two sources of power, or between, as the French would say, *charbon et houille blanche.*

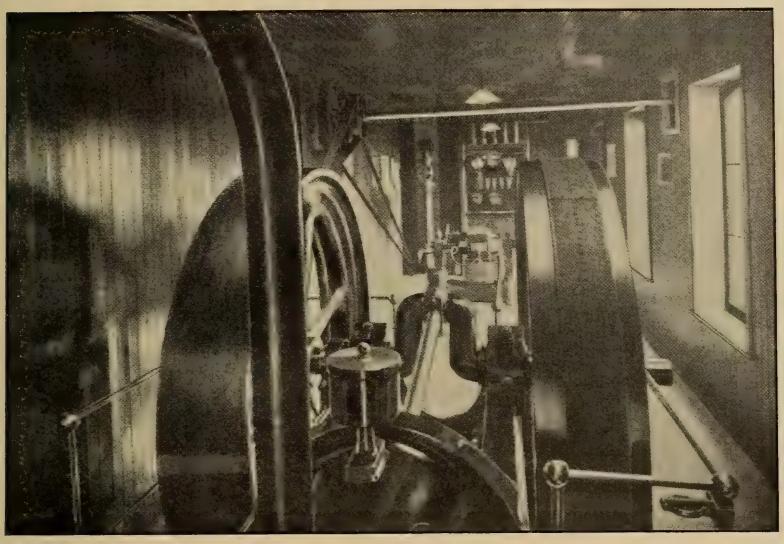
A TEST OF COMPARISON BETWEEN WATER AND GAS POWER

A test of comparison between water-power and blast furnace gas power should be determined by the following qualifications:—

a. The reliability of continuous supply over long periods of years.
b. The influence of weather changes on the continuity of the supply.
c. The net value of the economical advantages compared with the gross value.
d. The market for the power product.
e. Suitability for driving alternating electrical machinery requiring high cylindrical uniformity.

Of course, the *houille blanche,* or water power, would, *prima facie,* be incomparably superior measured by the qualification a; but it must not be forgotten that natural and terrestrial changes have suddenly diverted water courses, and the claims of owners of riparian rights may seriously influence the extent of the water-power available at a given point.

On the other hand, blast furnaces, in many well-established works, have been in more or less continuous operation for scores of years. The author remembers some twenty-five years ago noticing on a Lowmoor blast furnace mantel the date of its erection in 1789; it was still in operation in the eighties of 1800!



THE PIONEER FURNACE GAS ENGINE AND DYNAMO. 1894

In this connection it is interesting to record that it was on the advice of Dr. Priestley that the Lowmoor Iron Works was established, and in the first financial accounts of this company, in 1789-90, there is mention of a spirit-level purchased from Dr. Priestley. Priestley was the discoverer, along with Lavoisier, of the gas oxygen.

A RESERVE OF POWER

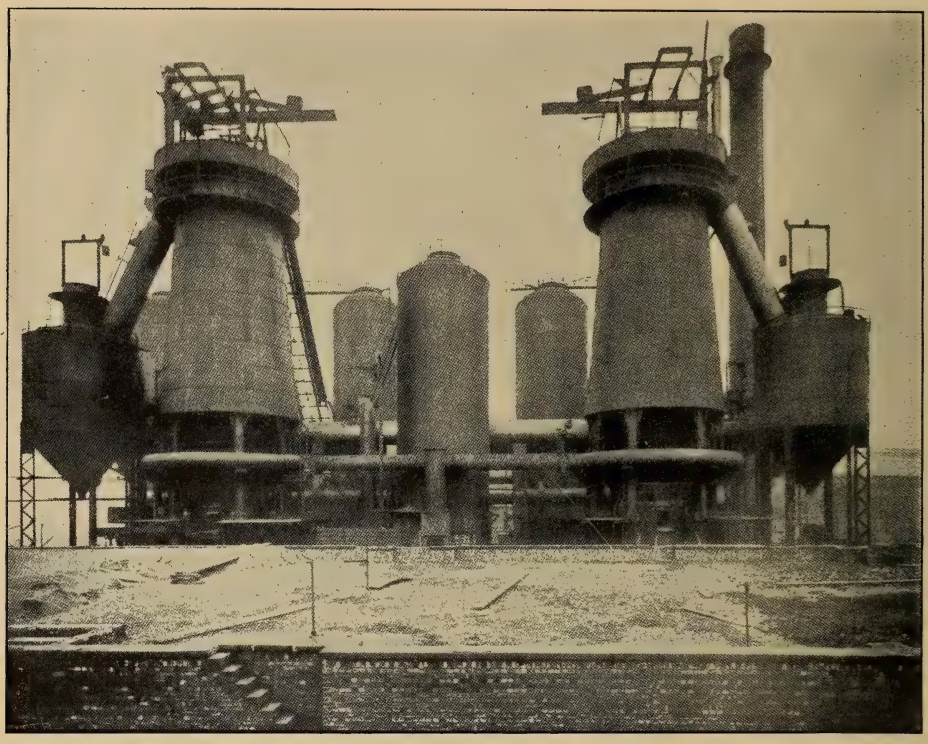
Of course, it would never be advisable to draw on the full available supply from any group of furnaces. The output from at least one furnace should always be held in reserve to allow for temporary stoppages, such as are involved in tapping, stove cleaning and other incidents of inactivity in blast furnace practice independently of market exigencies, which are, however, provided for by auxiliary gas generators. It may be said, however, that few, if any, of our manufacturing industries can show such remarkable maintenance of sustained operations as does a well-established iron works; besides, the additional service of providing power would, *per se,* tend to maintain the continuity of active operation.

b. The effect of weather on waterfalls of moderate proportions may be very serious. A long period of drought may dry up the watersheds; on the other hand, a long period of severe cold below zero may freeze the tributaries to the falls.

Against this, a slump in the market or bad trade may make it necessary to blow out one or more furnaces; this applies more particularly to newly established works.

c. The cost of a kilowatt-year at the water turbo-dynamo terminals varies between 32 and 80 shillings. According to a responsible authority, presuming the gas is delivered to the engines as a waste product, or gratis, the cost of a kilowatt-year of a large blast furnace gas dynamo should not exceed 66s. 8d. per kilowatt-year.

d. As we know, the blast furnace is usually in a centre of power demand, whereas waterfalls are often in badly accessible positions and far removed from existing manufacturing centres. This means that if electrical industries are initiated to take up the power, an additional cost in the transport of raw materials and finished products from the power station is incurred, and labour, if per-



ARRANGEMENT OF FURNACES AND GAS MAINS AT THE PARKGATE WORKS

haps more settled, is not nearly so plentiful.

Besides, on this question of establishing electro-manufacturing industries it can be demonstrated that an iron works is an ideal associate for many of the most profitable of the electro-manufacturing industries, because of the similarity of the agents of the iron industry and the electro-manufacturing ones.

For instance, take carbide of calcium; the author pointed out, ten years ago, that the agents—high-quality coke, high-quality lime—are both essential agents of pig-iron-making, and so they are for calcic carbide production. Again, the effluent gas, carbonic oxide, is a common residual product of both processes. The CO from the calcic-carbide furnace can be mixed with the CO effluent of the iron furnace to develop power. In making an economic comparison as a basis of selection of a site, the advantages set forth in favour of blast furnace power should not be overlooked; moreover, the utilization of a waterfall, even at home, does not benefit the master industry of iron making. If it is a question of deciding between a foreign-located waterfall power and that of home blast furnaces as sources of power production, the natural standpoint should not be overlooked, although in recent years this patriotic consideration appears to have little weight compared to its recognized value in Germany and in America, for instance.

A NATIONAL DUTY

It is an economic axiom that it is best to establish a factory, if possible, in the country that supplies the demand for the product of such manufacture, because this policy must necessarily assist in maintaining that country's prosperity. Blast furnace power at home is, therefore, on every ground, except perhaps net cost of power at the terminals, preferable

to that of waterfalls located in a foreign country. Therefore, the gross advantage in most cases will be found in the balance to be on the side of the blast furnace power, always assuming the good-will and entire co-operation of the ironmasters.

e. Assuming the water courses and tunnels leading to the turbine are well guarded against floating obstacles, and assuming a perfect balance of parts and proper lubricating arrangements, then the steadiness of running of a water turbine should reach almost cylindrical perfection.

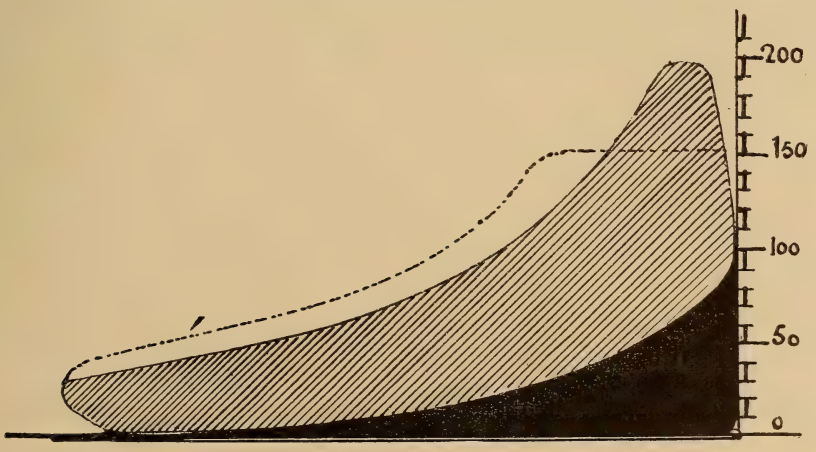
In blast furnace power practice this steadiness of running involves certain important qualifications which are briefly set forth as follows:—

An ordinary four-cycle engine (that is, with one effective power impulse in two revolutions of the crank, with the smallest number of reciprocations permissible in the large masses of reciprocating organs necessary in large power gas engines) cannot under any circumstances, except with an abnormally heavy fly-wheel, give the cyclical steadiness of running to drive alternating machinery acting in parallel that one could desire.

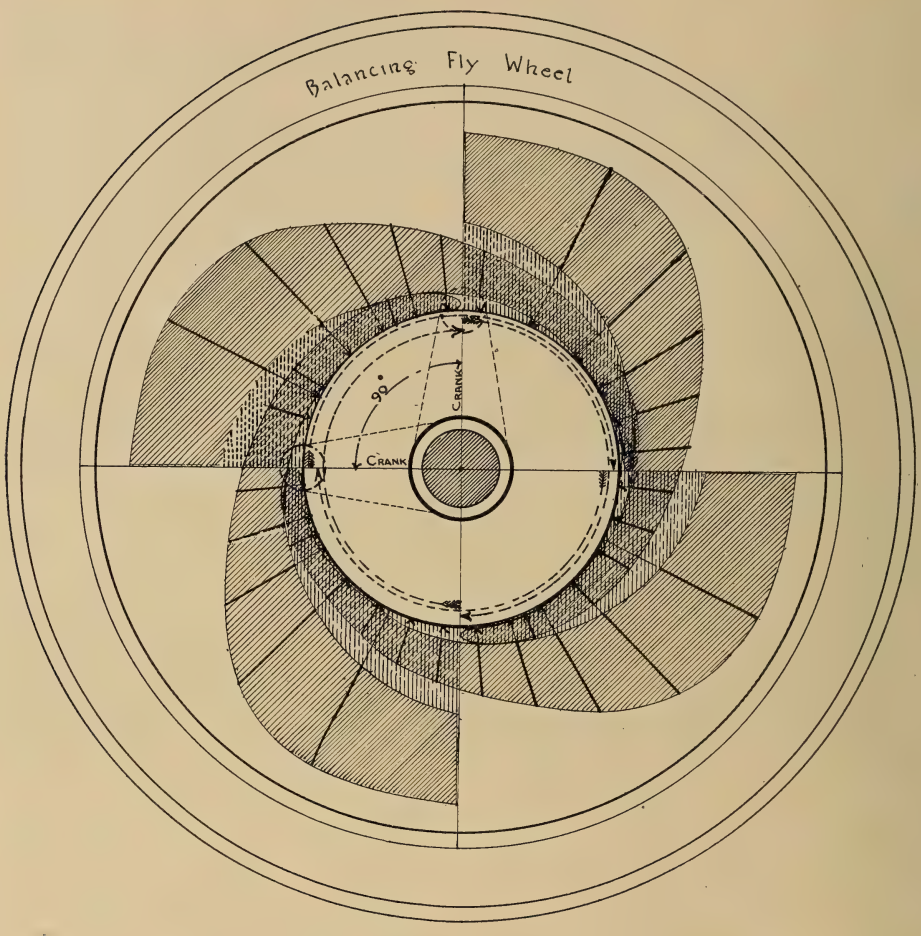
This was recognized, and especially by Continental engineers, as soon as the use of the blast furnace gas opened up the vista of the immense possibilities possessed by the internal-combustion engine. The indicator diagram shows the mild character of the explosion curve in the Otto cycle using blast furnace gas and its approach to the curve of an expansion.

It was believed to be impossible to duplicate the Otto cycle in one cylinder, but the low average temperature using blast furnace gas permitted this to be accomplished perfectly. Once this fact was recognized, all the difficulties in securing a near approach to perfectly even turning disappeared, and it is well known that if the balancing of the moving parts is carefully computed, it is possible to secure (with a double-acting set of two cylinders arranged either *vis a vis* or tandem, and with their cranks set at right angles to each other and with a fly-wheel alternator between the two cranks, and working in the Otto cycle) an extremely satisfactory cyclical regularity.

The question of vertical *versus* horizontal acting does not enter into this article, but the author's preference is in favour of the vertical type, which offers possibilities in balancing (and in reduction of the actual energy absorbed by the engine itself) that are absent in the horizontal type, independently of floor space and



COMPARATIVE INDICATOR DIAGRAMS FOR STEAM ENGINE AND GAS ENGINE USING FURNACE GAS



CRANK-CIRCLE EFFORTS ON FURNACE GAS ENGINE
Explosive effort shown by diagonal solid hatching; compression by vertical dotted hatching

dangers of unequal settlement of the foundations. The diagram shows graphically the well-distributed character of the movements of effort established on a crank circle of a blast furnace in a well-designed double-acting and multiple cylinder engine possessing all the refinements that skilful observation has evolved.

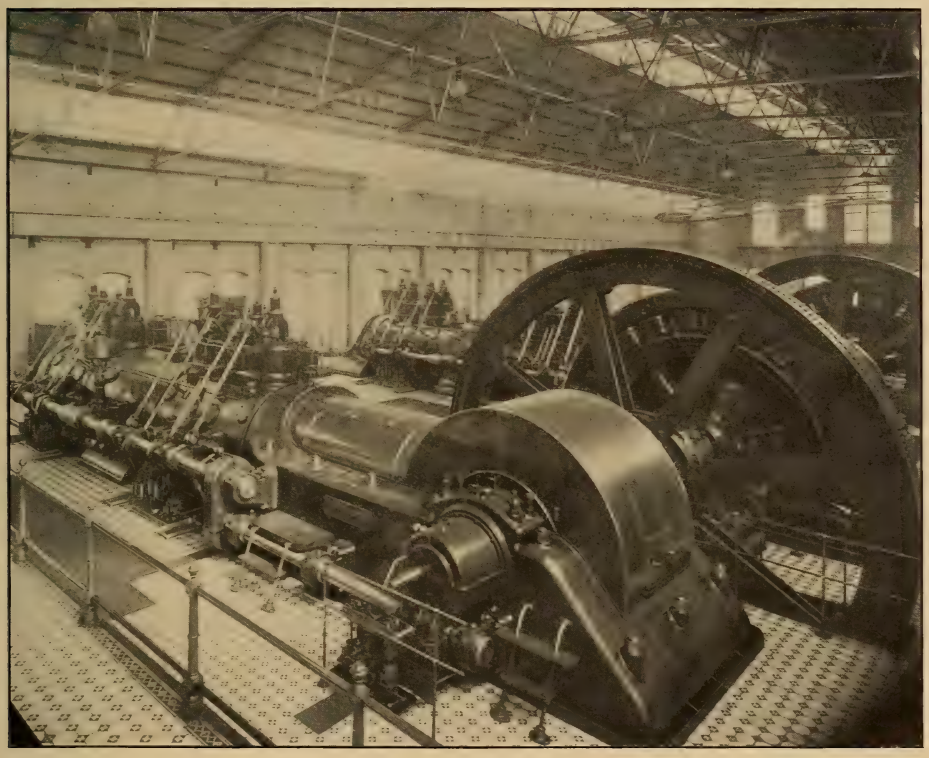
The cyclical steadiness of such engines has for some years been well established; it is well known that tens of thousands of kilowatts of energy are being developed in German iron-making centres alone, and no greater evidence of German enterprise could be elicited than is constituted by the history of the evolution of large gas power units in that country. As the author has pointed out,* much of this enterprise is the result of the excellent industrial banking system of Germany. Besides securing a better turning effect, the doubling of the effective efforts by completely enclosing the cylinder has primarily reduced the weight proportion of the moving and static parts of the engines compared with the unit of electrical horse-power, and, secondly, has equalized the flow of heat in the cylinder walls

*"The Rise of Germany" (a lecture), King & Son, Westminster.

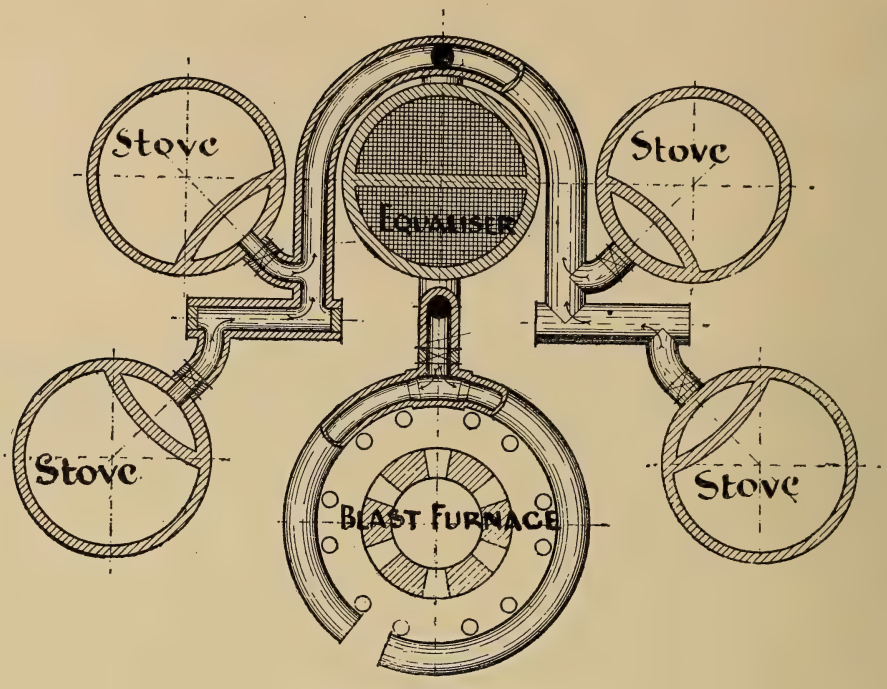
and consequently lessened the dangers due to unequal expansion, the *bête noir* of some makers of Otto cycle engines.

The illustrations represent some of the finest and most successful types of the Otto cycle double-acting cylinder engines of 2,000 electrical horse-power driving electrical machinery, but even this unit of power (2,000 E. H. P.) is small in comparison to what the immediate future may evolve in the vertical type of gas engine acting on blast furnace gas or its chemical equivalent.

Nevertheless, the margin of improvement that may be secured by increasing the power output of a gas engine is not nearly so wide as it is in steam practice. Obviously the thermo-dynamic efficiency of 30 per cent. attainable with small gas power units cannot be greatly extended by increasing the power unit. The high mechanical efficiency of modern well-made gas engines, if of the double-acting Otto type of even 250 electrical horse-power, does not leave any serious margin for increase by the enlargement of the power capacity; but there are the advantages of concentration and in reduction of organic parts and frictional surfaces proportionate to the output and the raising of the mechanical efficiency thereby; nevertheless, if the highest economy of thermal efficiency running is desired, it will also be necessary to have engines of graduated power leading up the power of the largest units of a station, so that if the load diminishes below three-fourths of the power of such large units the smaller power-units can take this load at their full power; but even the serious loss due to the half load-working of a gas engine (Otto cycle) is



HOESCH IRON AND STEEL WORKS. 2,000 HORSE-POWER GAS ENGINES. EHRHARDT & SEHMER, SCHLEIF-MUHLE-SAARBRUCKEN



HARRISON FURNACE GAS EQUALIZER

reduced by the double-acting Otto cycle types, and for obvious reasons.

It appears, therefore, that the entry of this advanced type of blast furnace gas engine has levelled down the points of superiority that were justly held to give the hydraulic turbine an unapproachable advantage in cyclical uniformity over the gas engine.

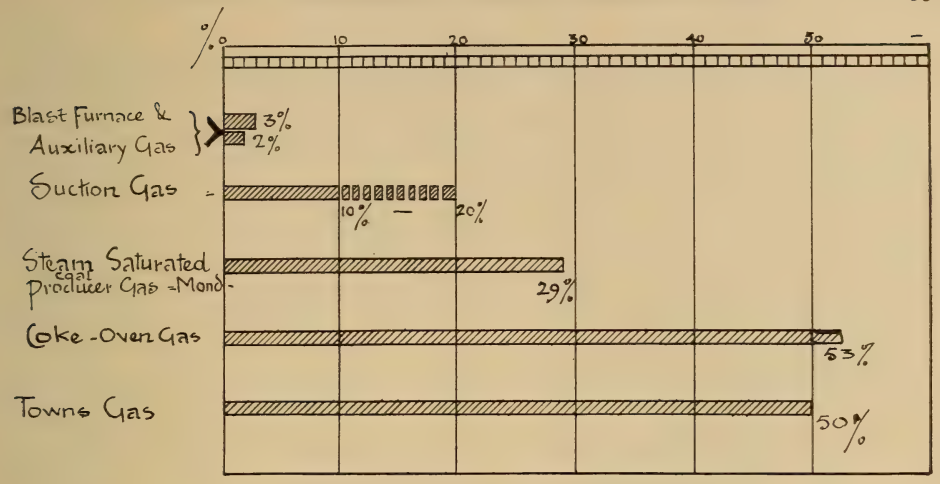
By distributing the reciprocal moments of energy applied around the four points of a crank circle, a steadiness of running, using blast furnace gas, can be secured that will satisfy the exigencies of cyclical uniformity of alternating machinery running in parallel.

UNIFORMITY OF FURNACE GAS

The great facts that, firstly, all the agents of iron making are fed into a blast furnace charging hopper with almost mathematical regularity; secondly, that the proportions of the materials and the column of fuel are very massive; thirdly, that the iron and slag are run off at more or less regular intervals; and fourthly, the air is fed into the furnace in volumes of equal pressure, if not of equal temperature and hygrometrical condition, all tend to secure a remarkable regularity of the chemical contents and of the thermal value of the blast furnace gas.

The variability of the temperature of the air blast, one of the variable agents, is due to two causes—first, to the principle of alternation or reversible as distinct from continuous recuperation in heating the air blast, and secondly, to the increasing inefficiency of heat transference of the heat-exchange surfaces of the hot blast stoves, due to the incursion and deposition of dust from the dirty or unpurified blast furnace gas. The influence, measured thermally, is to reduce the air-blast temperature from 1,300 degs. F. to 900 degs. F. and even lower temperatures.

The remedy for the first irregularity is to employ Harrison's equalizing stove. This apparatus acts as the name implies, equalizing the



PROPORTIONS OF HYDROGEN IN VARIOUS FUEL GASES

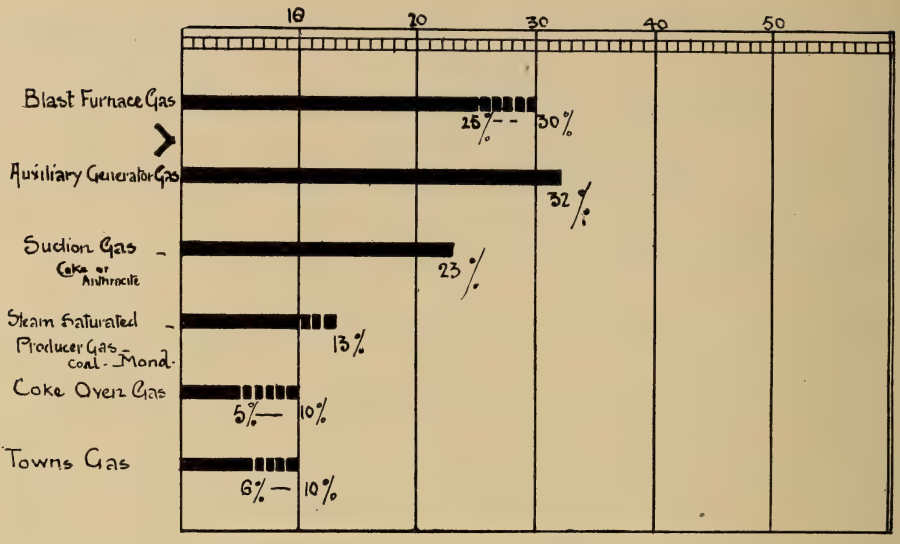
temperature of the blast; it is really an accumulator of heat through which the air blast from all the stoves has to pass on its way to the tuyeres. This apparatus is shown in the illustration, and it deserves a place in every progressive iron works.

The remedy for the second defect, a remedy advocated by the author since 1896, is to remove the suspended dust from all the blast furnace gas, and with as little loss of sensible heat as is practicable.

The hygrometric variation of the air, the second variable element, is shown in the small daily changes in the proportion of hydrogen present in furnace gas. Fortunately, the maximum proportion of hydrogen in the gas due to the moisture in the air does not exceed, under normal weather conditions, more than 3 to 4 per cent.; but a leaky tuyere has been known to increase this proportion, with the result that premature ignition has reversed engines and associated dynamos when running at 120 revolutions, so that increasing care of tuyere equipment is advisable when gas engines are associated with furnaces.

The refrigerator principle, introduced by Mr. Gayley, will remove this hydrogen variation, but at the expense of the reduced thermal value of the furnace gas, which is brought in thermal value down to as low as 75 B. T. U. per cubic foot; but this reduction of thermal value does not materially affect the suitability of the gas as an agent of power production. The author has secured steady and constant running with a gas of much lower thermal value than this. Nevertheless, any calculation defining the advantages of refrigerated air should debit the system with the reduced power value of the furnace gas. The suppression of the hydrogen per second is really no disadvantage, except through the slight loss of thermal value associated with it. This appears in the accompanying diagrams, showing the proportions of carbonic oxide and hydrogen in representative power gases.

The fact that hydrogen is probably ten times more sensitive to ignition influences than carbonic oxide, explains why its use in large power cylinders with low-speed reciprocations, and with high compression, is so risky. The author, in his first run of his pioneer engine, ran up the compression from 40 pounds, the normal compression limit, to 80 pounds. All attempts, prior to the author's patent of 1894 for using gas equivalent to furnace gas, to build what were in the eighties considered to be large power engines of, say, 200 to 300 horse-power with high-speed reciprocations, were failures



PROPORTION OF CARBON MONOXIDE IN VARIOUS FUEL GASES

more or less. With small engines, however, and low degrees of compression not exceeding 40 pounds, there is found to be no difficulty in using town or retort and other highly hydrogenized coal gas*, but the rapidity of its inflammation makes it unsuitable for the low rate of reciprocations necessary with large gas engines. The author has mentioned that in the first experiment with blast furnace gas he increased the compression from 40 to 80 pounds. He realized that to secure the ready ignition of a gas of such low calorific value that would barely keep a light in a boiler furnace it was essential to employ physical compression to secure the necessary density and sensitiveness of ignition. To-day compression figures of 150 pounds to the square inch are common, and in well-designed engines the indicator card shows that the energy, stored in the compressionable and elastic medium of a gas and air mixture, is returned with a merely fractional loss, so that in a well-proportioned engine, with cranks set at right angles to each other, the work of compression in one cylinder may be balanced by the return of this energy in another and associated cylinder. The high degree in the steadiness of running of a well-designed blast furnace engine with multiple and double-acting cylinders (Otto cycle) will be understood from the symmetrical proportions of the graphic diagram given on page 30.

Any doubt as to the competency of the furnace-gas engine to rival the hydraulic turbine will, the author trusts, have been demonstrated. The comparative economic advantage of the two systems can only be properly determined by crediting the furnace power with the value of the advantages not possessed by water power relating to transport, etc.

THE COEFFICIENT OF POWER OUTPUT PER TON UNIT OF IRON OUTPUT PER HOUR

What are the power potentials of a normal British blast furnace? The horse-power value of a blast furnace of a given daily pig-iron output obviously depends upon the efficiency of its constituent and associated ele-

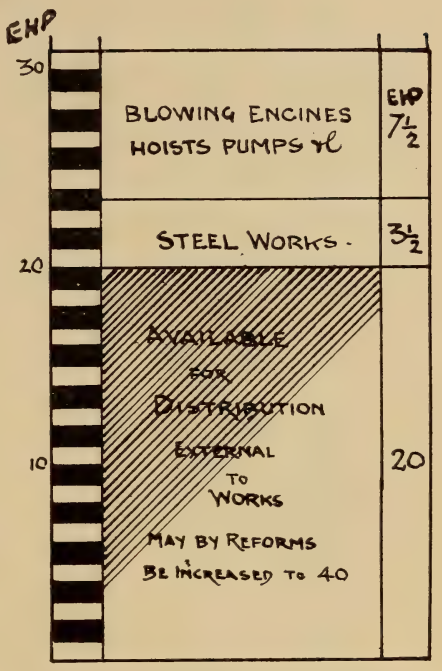
*The disastrous results following the attempt to use gas of high hydrogen contents for driving municipal electric supply generating stations with power units of even moderate capacities, has prejudiced the public against gas power, but once it is realized that it is not the power gas system, but to a great extent the excessive proportion of hydrogen in the gas, this prejudice will die away on the face of the stupendous evidence of the continental success in gas power dynamos, using low hydrogen content or blast furnace gas.

ments; but accepting the hot blast stoves as they are usually worked, *ergo,* with dirty gas, and assuming the output of the furnace to be equal to 100 tons of iron per diem, and allocating 1,100 electrical horse-power for blowing and steel works requirements, the power of such a furnace in excess of internal requirements will be equal to 2,000 electrical horse-power; that is to say, for each 4.165 tons of iron of a furnace per hour then 2,000 electrical horse-power will be available for distribution, equivalent to 480 electrical horse-power per ton of pig-iron per hour.

This figure will be considerably increased when the furnace gas allocated to the hot blast stove is denuded of its efficiency-destroying dust. (*Vide* the author's paper read in 1903 before the Iron and Steel Institute, "On the Effect of Flue Dust Upon the Thermal Efficiency of Hot Blast Stoves".)

It has been computed by one authority that with all the iron and steel works power-absorbing agencies brought up to a high state of efficiency, and with all the furnace gas efficiently purified, an available power of twice the figure named, or 960 electrical horse-power per ton of iron output per hour, would be available for electrical distribution external to the works; but if we take the output at only 2,000 electrical horse-power per 100 tons of iron per day, a normal group of three active furnaces, allowing one for reserve, would secure a substantial output of 6,000 electrical horse-power. With structural and process reforms an output of 12,000 electrical horse-power would most probably be secured.

It has been suggested by the author that it would be better and more economical if the hot blast stoves were fired with producer gas generated from an inferior kind of slack coal, allowing the whole of the blast furnace gas to be allocated for the production of power for which it is ideally suitable, then the power output of a furnace would be increased to a very high figure (*Vide* the author's paper on this subject, read before the Glasgow Engineering Conference in 1901).



PROPORTIONAL UTILIZATION OF POWER FROM FURNACE GASES

THE PIG-IRON OUTPUT OF 1906, AND ITS POSSIBLE POWER OUTPUT

The enormous power output possibilities of the world's blast furnaces:

Great Britain	France.	Germany.	U. S. America.
Tons.	Tons.	Tons.	Tons.
10,149,388	3,319,032	12,478,067	25,307,191
E.H.P.	E.H.P.	E.H.P.	E.H.P.
1,114,400	360,000	1,366,000	2,773,200

N. B.—It may be roughly stated that the power output of a furnace (per hour) is 1-10 the yearly iron output.

Taking the estimated world's production of iron to be equal to 60,524,505 tons, then the possible power output attainable by the adoption of all reforms available for distribution will be equal to 6,328,000 electrical horse-power.*

For Great Britain.	For France.	For Germany.
E.H.P.	E.H.P.	E.H.P.
1,136,000	359,000	1,280,000

*Mr. Leon Greiner's figures for 1905:

The full attainment of the possible power output will only be secured by

1st.—Using cleansed, in place of dirty gas, for the stoves; or, better still, as already mentioned, divert all the blast furnace gas for power production services, using common producer gas for the hot blast stoves.

2d.—Preventing the serious waste of gas during the furnace charging operations.

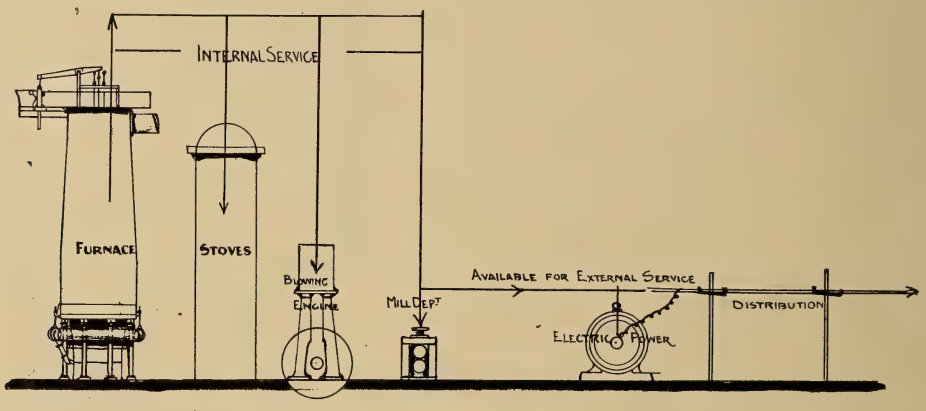
The economics of the principle of removing moisture from the air by refrigerating processes has been mentioned, but this system will, unfortunately, reduce the power output per unit of iron output of a furnace by

1.—The lessened heat value of the gas.

2.—The absorption of power in driving the refrigerating machinery.

Allowing for every possible reform in blast furnace practice, to secure the fullest thermal efficiency of all the heat assets of the coke or coal charged into a blast furnace, it will be possible to rely upon an external service of 4,000 electrical horsepower in every hour of a day, per each output of 100 tons of iron per diem. of twenty-four hours.

It is impossible in any consideration of the economics of the blast furnace and its associated apparatus to forget that there is an enormous waste proceeding in the process of coking to satisfy the colossal demand of the world's furnaces.



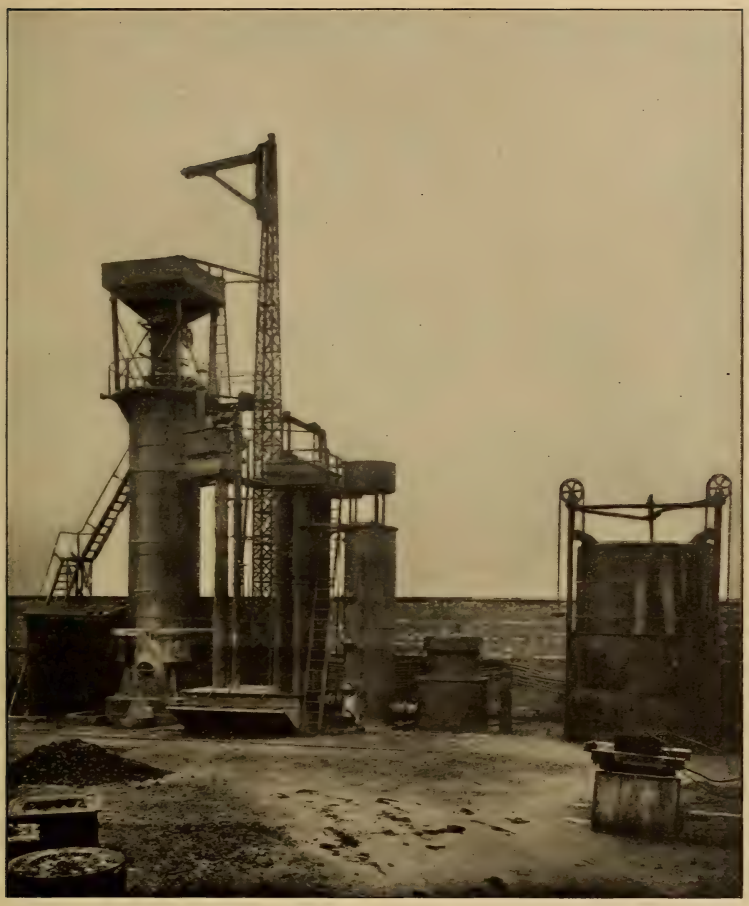
DISTRIBUTION OF FURNACE GAS POWER

THE POWER POTENTIAL OF THE BY-PRODUCT COKE OVEN

The magnitude of the proportions of the weight of residuals that might be recovered if all the coal were coked in well-designed by-product ovens to satisfy the blast furnaces is inadequately represented by the folfowing figures:—

The weight of sulphate of ammonia recoverable approximately should imate weight of tar should equal 1,300,000 tons. In addition to this, equal 1,500,000 tons, and the approx- assuming that 35 per cent. of the effluent gases satisfies the internal demand of a modern by-product coke oven, then the power potential of the gases is no less than two and one-half millions of effective horsepower for each hour of the year.

Of course, it cannot be assumed that with widely scattered coke ovens it would be possible to profitably harness all or any of them; but when the coke ovens are adjacent to any group of blast furnaces which are electrically harnessed, as proposed in this article, it will be possible to combine these gases in such a way as to reduce the average proportion of the hydrocarbons and hydrogen in the gas to within advisable limits to secure regular running operations.



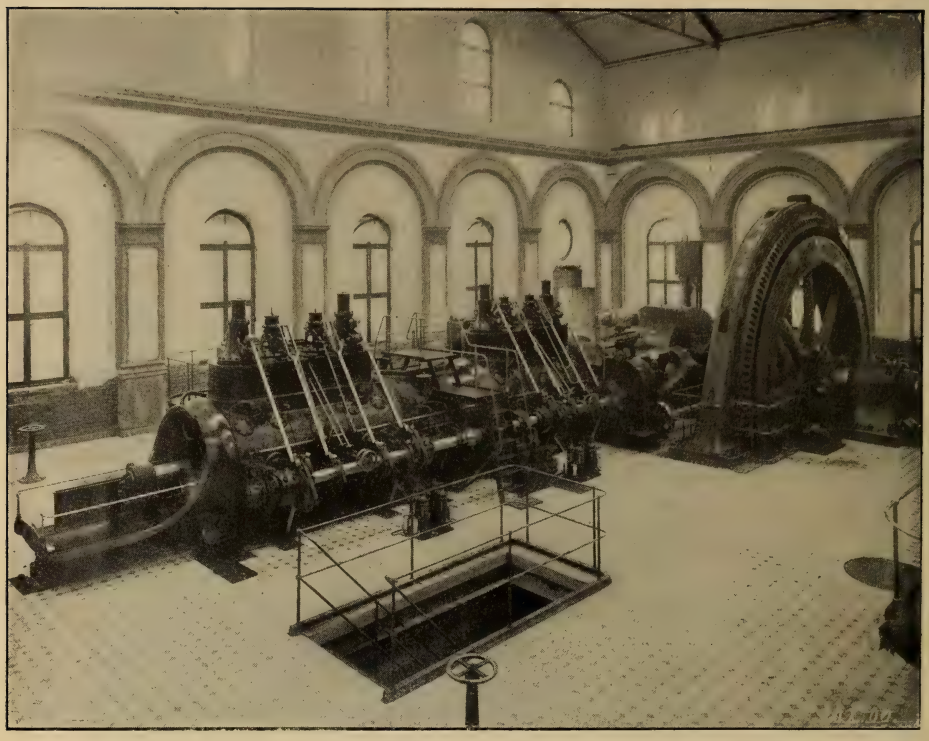
GAS POWER PLANT FOR 500 HORSE-POWER

A POOLING SCHEME

The author has, in a paper contributed to the recent September meeting of the Iron and Steel Institute, suggested for the consideration of iron masters a scheme of pooling furnace gases from all the furnaces in iron-making centres and independently of their ownership. The advantages set forth in favour of this scheme are enumerated in the paper as follows:—

Recapitulating the advantages of pooling, it may be said that besides facilitating the electrification of the rolling mills by the reduction in capital cost of plant, it will secure, in addition to the advantages of electrical driving, a substantial increase in the proportion of the furnace power gas available, by the suppression of the mill steam boilers. The pooling proposition will constitute an ideal combine, securing all-round benefits to the iron master and the power consumer, and tend to promote the establishment of new electrical industries and thus enlarge the field of demand for power, it will financially justify expenditure in apparatus, in technical changes to secure the fullest possible economy in the use of furnace gas in the works.

That in both Germany and the United States the adequate measure of the power capabilities of an iron works is being recognized, is evident from the scheme of power production in use or to be carried out in the following two representative works. In the new iron and steel works at Gary the United States Steel Corporation are installing a gas-engine and electric plant of some 40,000 electrical horse-power to use



BLAST FURNACE GAS ENGINE BUILT BY THE GAS MOTOREN FABRIK, NURNBERG

blast furnace gas, and at the Krupps Rheinhaussen Works it is stated that twenty-six blast furnace gas engines are developing amongst them no less than 36,000 electrical horse-power.

In England the characteristic apathy that is the normal and disheartening attitude relating to new developments is at last being overcome, and only last year the Royal sanction was given to an Act which has for its object the harnessing of the waste gases from the furnaces on the Cumberland coast for the service of the county electric power requirements and for encouraging the establishment of new electrochemical and metallurgical industries, so that we are well justified in believing that even in Great Britain the blast furnace is assuming, if gradually, the great rôle for which it is so ideally fitted, and the practical assumption of which will increase the value to the community of the blast furnaces, and add to the prosperity of, and strengthen, and steady the master industry of ironmaking, the prosperity of which means the prosperity of a nation, whilst its converse means adversity.

A GAS-MAKING AUXILIARY TO THE BLAST FURNACE

In the 1906 Proceedings of the American Institute of Mining and of Mechanical Engineers, it was pointed out in the discussion that the author had invented an auxiliary gas generator designed to produce gas as near as practicable identical with blast furnace gas.

Such a generator is illustrated herewith. The character of the gas is reproduced by the following analysis:—

$CO = 32.4$ per cent.
$H = 1.6$ per cent.
$CH_4 = 0.6$ per cent.

The slag is highly fusible, and is readily converted into slag wool.

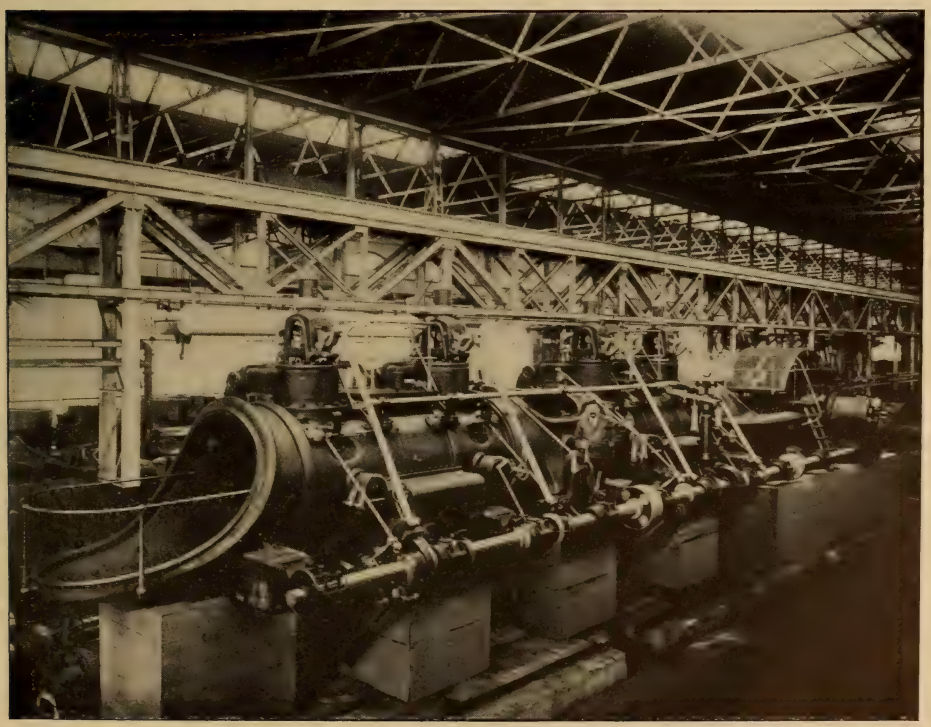
Producers of this type (capable of

generating in two to three hours notice 2,000 electrical horse-power equivalent of gas per hour) are essential standbys for every blast furnace drawn upon to supply gas for an electric power bulk supply station.

In any group of blast furnaces it will be easy to arrange the working of the different furnaces so that the tapping operations shall not overlap, because this would mean a cessation of the gas supply, which can be met either by the regular service of the author's auxiliary generator or by the employment of a large capacity gas holder; the latter is, however, of only a limited and rigidly defined service, whereas the former is elastic and can continue for hours or during any temporary stoppage of a furnace. A famous Continental iron works is already installing such auxiliary generators to meet the vagaries and normal stoppages of small duration of the furnaces which are supplying gas to power gas engines of several thousands of electrical horse-power capacity.

A SOURCE OF ENORMOUS WASTE OF POWER

Where blast furnaces are associated with a steel works the excess gas from the furnaces has hitherto been led to the steam boilers of the mill departments; but, as it is well known, the waste of power by this method is serious; until quite recently the problem of effectually driving the large rail mills and other heavy machinery of a steel works has remained unsolved, and the unsolved problem stood in the way of the complete electrification of the steel works; but a solution of the problem has been obtained, thanks again to the splendid enterprise of Continental engineers and ironmasters, and within the next ten years most of the progressive works will,



BLAST FURNACE GAS ENGINES OF 2,000 HORSE-POWER, BUILT BY THE GAS MOTOREN FABRIK, DEUTZ

it is fairly certain, be conspicuously noticeable by the absence of the steam boilers and steam engines of any kind. In this connection the author is reminded of a conversation he had with the late Col. James Stuart Reid, of Glasgow, who said to the author in the early days of the author's pioneering work:—

"If you succeed in driving the steam engine and its wastes and nuisance out of our iron and steel works you will earn my deep gratitude for this alone, independently of any saving that may accrue from the reform."

Thanks, firstly, to the modern perfections of gas-driven blowing engines, and secondly, to the cyclical uniformity of modern multiple-cylinder, Otto cycle, double-acting engines; thirdly, to the electrical harnessing of heavy rolls, and indeed of all the machinery of a modern iron and steel works, all difficulties in the way of establishing the blast furnace as a source of power have disappeared.

Separate groups of blast furnaces in any iron district can be drawn upon, by the author's pooling proposition, to feed a centrally located electric power generating and distributing station, from which the electric supply (ear-marked to the extent to satisfy the internal demands of the iron and steel works) can be distributed to all the country round by aerial conductors, and at a very low cost in distribution equipment. The Board of Trade having wisely removed most of the grandmotherly restrictions, we shall yet see our blast furnaces providing power and light throughout the great manufacturing centres of England and Scotland, not with the ruddy flames of the furnace gas at the summit of the furnaces and through their great candlesticks, as did Col. Dunlap's furnaces in the early days of the Scottish iron trade. The great tongues and bursts of flame issuing from Dunlap's furnaces effectively lighted a north-eastern district of Glasgow, giving welcome illuminations which the people seemingly appreciated, and which prompted the local poet to voice the public gratitude in the following expression:—

"We are muckle oblieged to you, Colin Dunlap,
You're really a worthy old patriot chap,
Tae enlighten the country sae, Colin Dunlap."

But besides the blast furnace power proposition providing this illumination in the most perfect or in the electrical form it will secure other advantages; for instance, there will be no danger of boiler explosions, and the small demand for water will make the system independent of drought periods; besides, the great clouds of dust issuing from the stacks of our furnaces which are now polluting the atmosphere would be prevented.

It is difficult to imagine a reform possessing such possibilities of advantage to an industrial and commercial nation as that which would harness the furnace gases for power purposes for electrical transformation and distribution, both inside the iron and steel works and outside, and to satisfy any group of power-users anywhere within 25 miles from the blast furnace power distributing station.

THE DEVELOPMENT OF THE LARGE GAS ENGINE IN AMERICA

By E. T. Adams

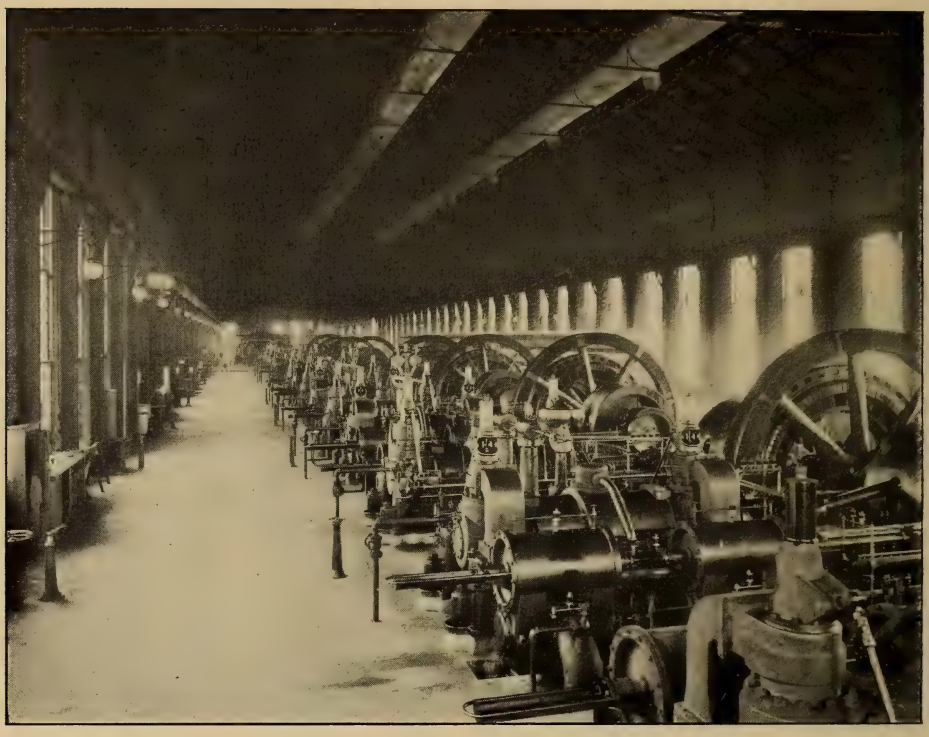
IN the United States there have been three stages in progress toward the utilization of blast furnace gas in the cylinder of the gas engine—the early experimental, the splendid pioneer performance of the Lackawanna Steel Company, and the present stage, which marks the beginning of the general use of the gas engine at all blast furnace plants where there is a demand for power in excess of that required to blow the furnaces. Between each stage there has been a long period of inaction, during which it seemed that both operator and manufacturer had abandoned all thought of checking the tremendous waste energy due to the imperfect use of these so-called "waste gases."

In Europe, on the other hand, under pressure of high fuel cost and with the stimulus of low cost of labour, continuous effort has been rewarded by uniform progress, and in the European iron and steel industry the gas engine has long held that commanding position as a prime mover which, in America, it has only won within the present year.

When the degree of success attained by gas engine manufacturers with engines using natural gas first gave rise to the hope that a reliable engine of 500 to 1,000 horse-power could be provided, the Pennsylvania Steel Company installed a small engine at their plant at Steelton; the installation was purely experimental; the engine was of the then popular three-cylinder vertical type designed for natural gas; the crank case was enclosed, and bearings, pins and valve gear were all lubricated by the splash system. In these days "gas engine troubles" were very real and ever present, but after patient experiment a point was reached where steady operation seemed assured. It was found impossible, however, to prevent the abrasive dust carried by the gas from working down past the piston into the lubricant in the bottom of the crank case, thus causing the speedy ruin of all the bearings and the end of the experiment. A larger engine of the same type, installed in one of the Carnegie plants, failed from a similar cause, and there ended the attempt to utilize the vertical single-acting type of gas engine in blast furnace service.

The manufacturer again turned his entire attention to the great and profitable trade in the natural-gas belt, and the furnace man again turned the waste gases from his furnace under a boiler and waited the advent of a new and better type of engine. Then came Lackawanna.

In 1901, when the new plant of the Lackawanna Company was built at Buffalo, N. Y., a great central power plant was installed, consisting of sixteen blowing engines rated at 2,000 horse-power each, and eight electric units rated at 1,000 horse-power each. The engines were built by the De La Vergne Company, of New York, from drawings furnished by Mr. Ernst Koerting. At the time this plant was built the war of the types, the "two-cycle" versus the "four-cycle," was at its height, and the question as to the proper system



GAS POWER PLANT AT LACKAWANNA WORKS, BUFFALO. KOERTING ENGINES BUILT BY DE LA VERGNE MACHINE CO.

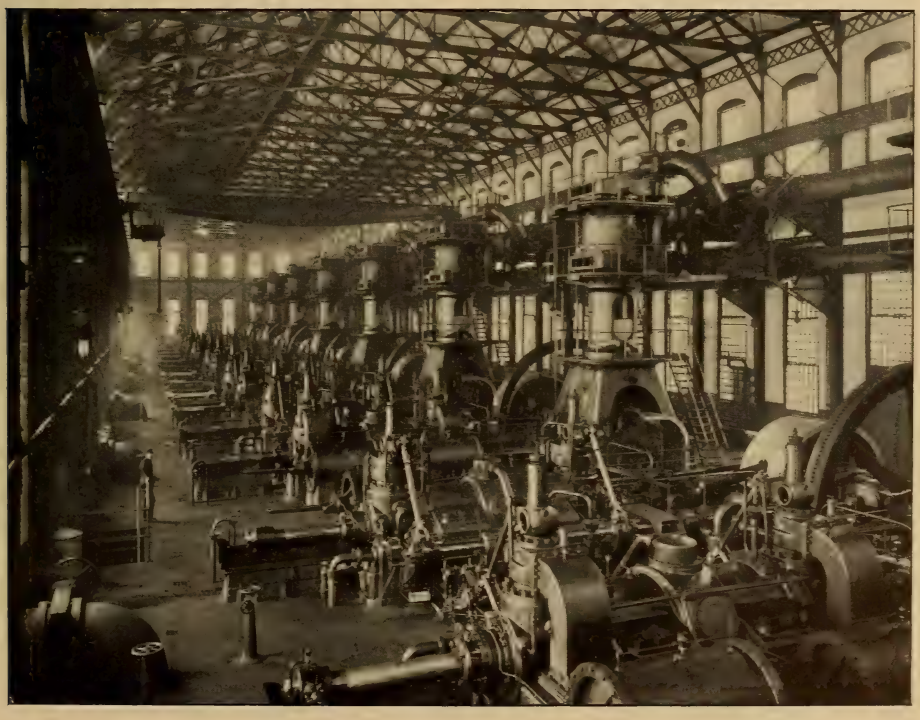
of washing gas from furnaces using the finer grades of American ore was also being sharply discussed. It was perhaps natural that the superintendents and managers of the great steel plants should wait to see these matters sifted to a solid basis and to observe the outcome at Lackawanna before taking any action themselves. Therefore, it came about that a second period of inaction, not wholly expected at the time, followed the installation of this plant. This time the inaction was apparent rather than real; true, no purchases were made, no gas engines were installed, but it was a period of active preparation for the final stage manifestly near at hand—the universal adoption of the gas engine as the prime mover in all blast furnace plants.

In 1905 the officers of the United States Steel Corporation determined that the gas engine should be used in all new work and extensions of their various plants, and in the fall of that year they placed their initial order for two gas-driven blowing engines rated at 3,000 horse-power each. These engines were for an extension of the Edgar Thomson Works of the Carnegie Steel Company at Pittsburg, and were not completed and put into service until the spring of 1907. The installation of these engines was not in the nature of an experiment, and further action did not await results at Edgar Thomson. The action of the officers of the steel corporation was based on intimate knowledge of all that had been accomplished both abroad and at home, and as new equipment was needed new orders were placed, and placed at a rate that found nearly 200,000 horse-power on order when the successful operation of the Edgar Thomson blowers finally demonstrated the soundness of the position which they had taken. This figure has greatly increased since the engines at the Edgar Thomson plant

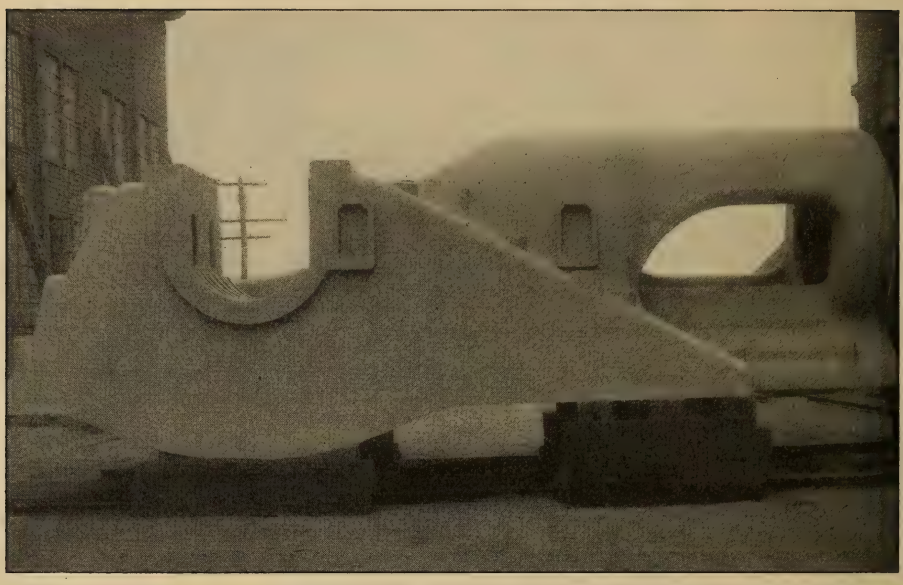
went into service, and to-day there are, in round numbers, 350,000 horsepower of gas engines in operation, or on order for use in the steel industry in the United States.

An interesting phase of this huge volume of business is the immense sum which the gas engine manufacturers of the United States have staked on the judgment of their engineers and superintendents, for it must be borne in mind that all these engines are from new designs, and nearly all are far greater in size than any engines in similar service either at home or abroad. With untried designs solidifying in iron and steel at the rate of over 100,000 pounds daily, month after month, as was the case with some, it may be imagined that there was universal rejoicing when the time came, as it did at length, that nearly every week saw an engine swung successfully into regular service. It was of little moment to any one who had built that particular engine; it was one more added to the list of those who had made good at a time when success, no matter by whom achieved, strengthened the position of all.

Any detailed description of the various designs is beyond the scope of this paper, but certain features are noteworthy. All these engines are of the horizontal, double-acting four-stroke cycle type. All are single crank or "side crank" design as opposed to the "centre crank" design with its double bearings in universal use abroad. The illustrations of gas engine frames, as designed by the Snow and Allis-Chalmers Companies, show these features very clearly, and show the distribution of metal selected to resist the bending stresses set up in an engine frame of this type. Either design of frame weighs about 90 tons for a 42-inch by 54-inch engine. In both designs spreading of the jaw of the main bearing is prevented. The Allis-Chal-

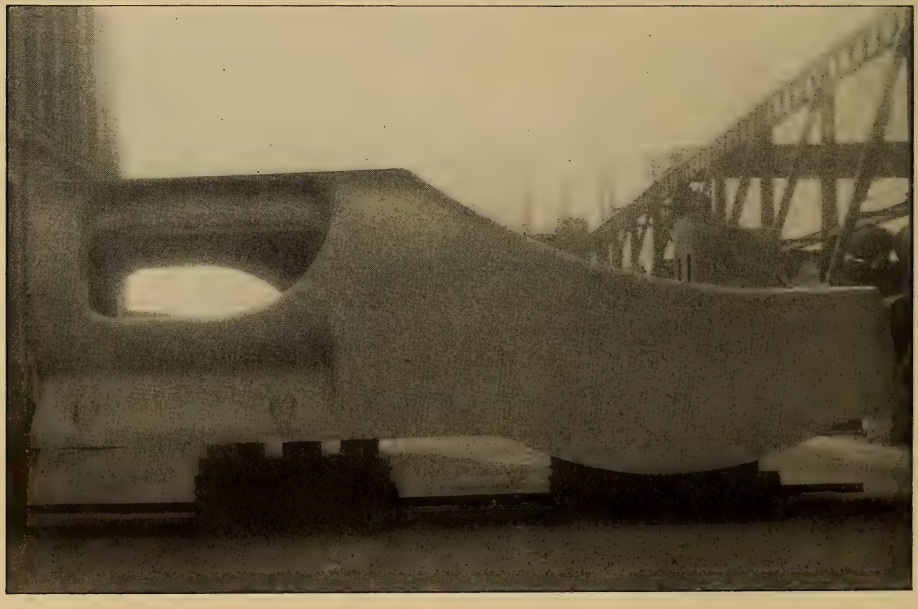


GAS-DRIVEN BLOWING ENGINES AT THE LACKAWANNA WORKS, BUFFALO. KOERTING ENGINES BUILT BY THE DE LAVERGNE CO., NEW YORK

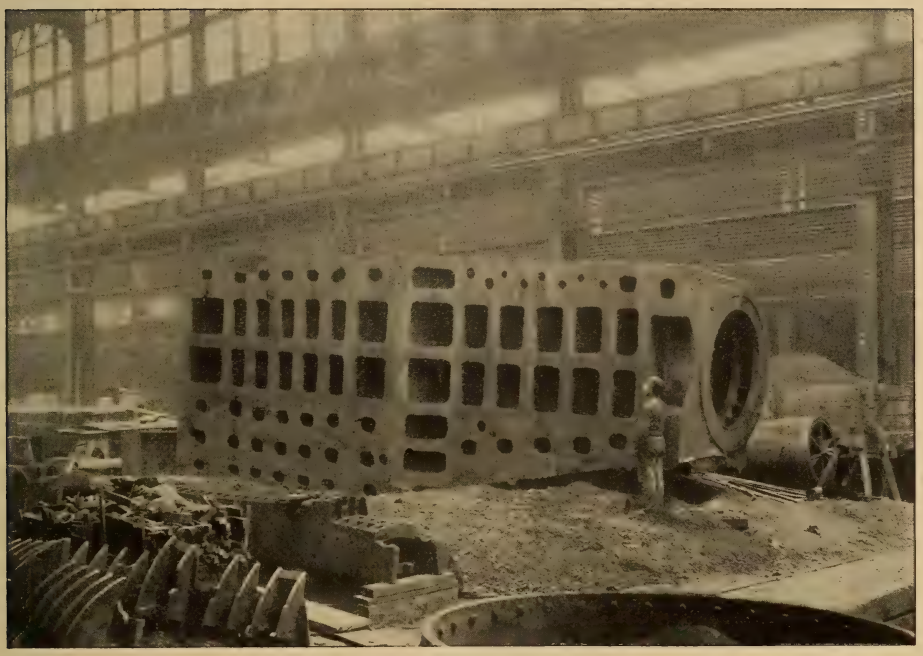


FRAME OF 42-INCH BY 54-INCH SNOW GAS ENGINE, SHOWING MAIN BEARING

mers Company use two through bolts above the shaft, as the illustration clearly shows. The Snow Company use a very heavy cap extending down at each end over the jaw, and wedges between the jaw and cap. The method of avoiding internal strains in the casting and the deep girder effect under all foundation bolts is obvious. The ability of these frames to resist the action of the stresses which develop in any single crank design is also very materially aided by the design and arrangement of



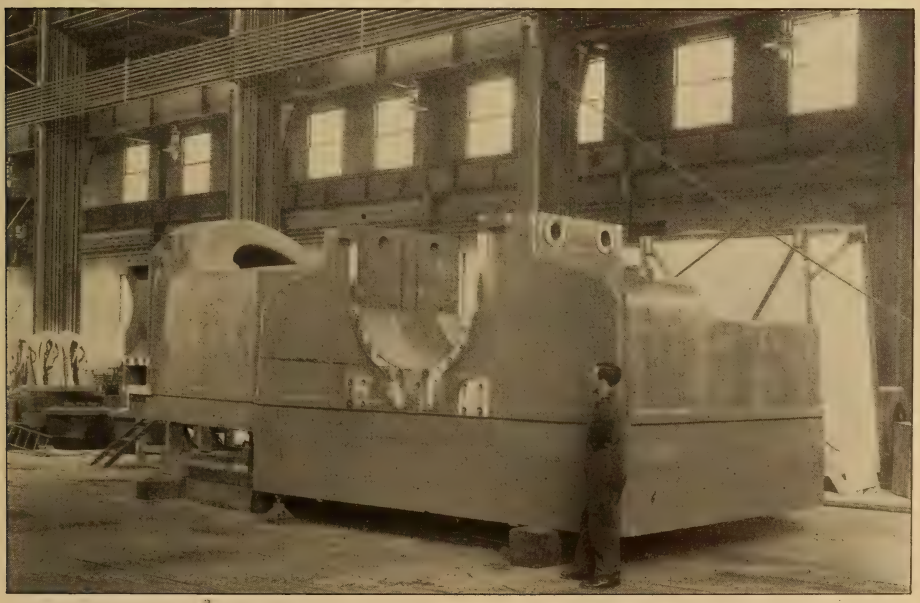
SNOW GAS ENGINE. FRAME OF 42-INCH BY 54-INCH MACHINE



FRAME OF 44-INCH BY 54-INCH ALLIS-CHALMERS GAS ENGINE

the foundation bolts, which unfortunately could not be shown in the views selected.

A like uniformity of opinion is shown in many other features of design. One builder offers a throttling or variable-compression engine, three use some form of cut-off gear



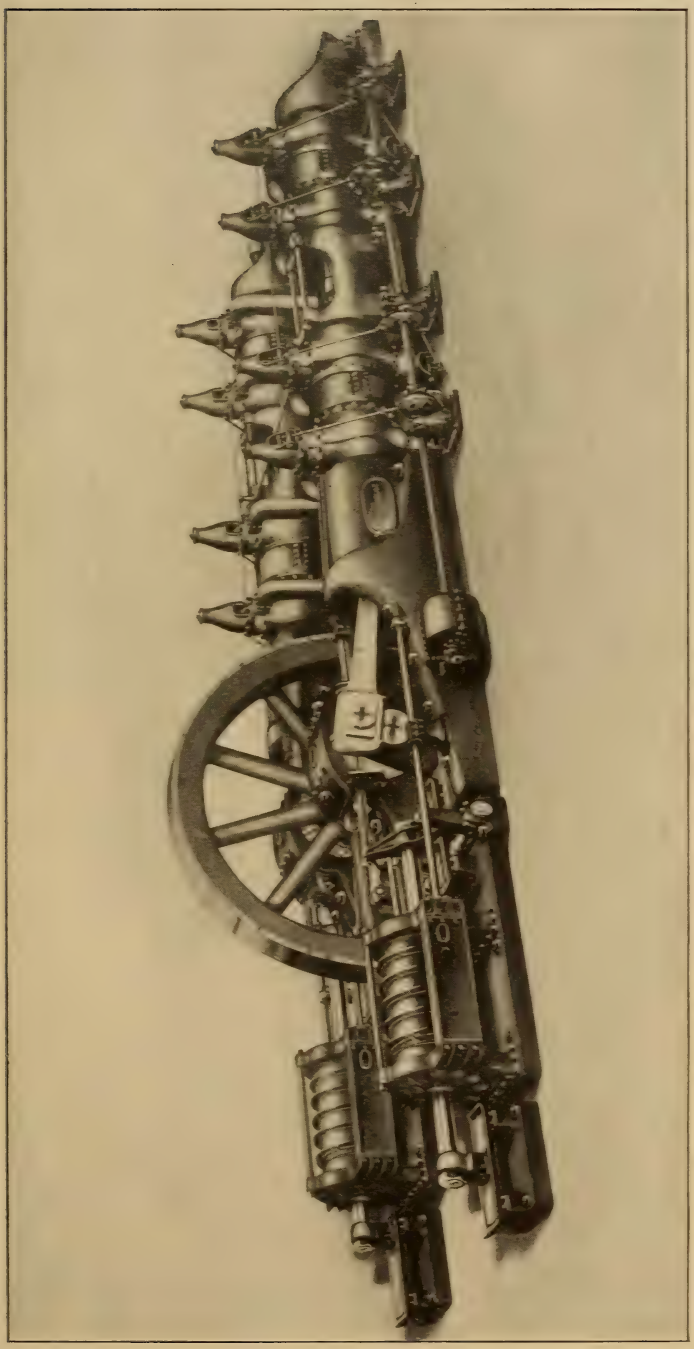
GAS ENGINE FRAME, SHOWING MASSIVE CONSTRUCTION. ALLIS-CHALMERS CO., MILWAUKEE

and constant compression. The valve gear of three builders is eccentric operated. One builder uses a cam-operated gear. All the blowing tubs or air cylinders are of the Slick type. The air cylinders in every case are located ahead of the frame and in line with the gas cylinders, the air piston being driven by rods from the main crosshead. The weight per horse-power is greater than that of European-designed engines. The tendency toward simplicity in the valve gear design is also very marked.

To one who has had the opportunity to examine the design both here and abroad, the influence of European experience is apparent; but while it is certainly true that the larger American gas engine owes much to Continental design and experience, it owes more, and, in fact, derives its characteristic features, from that intangible and undefinable but very real thing—"American practice." At the American blast furnace there is one great law:—"Get tonnage." No man may violate this law and live, and no excuse is accepted for failure to obey. The American gas engine also becomes amenable to this law, and it is this that has made the deepest imprint on American design. Ability to go and keep going to the end that we get tonnage, this is first, and all things else have been made subservient thereto.

After Lackawanna, the first large gas engines to go into service on blast furnace gas were the two gas engine-driven blowers installed at the Edgar Thomson Works of the Carnegie Steel Company, of Pittsburg, and built by the Westinghouse Machine Company, of the same place. These engines, which are shown in the illustration on the opposite page, are horizontal twin tandem engines, and have four double-acting gas cylinders, each 38 inches in diameter by 54-inch stroke. The air cylinders, two in number, of the Slick type, are located ahead of the frame, and are each 60-inch by 54-inch. The usual speed of this engine is 60 revolutions per minute. The exhaust valve here is similar to the Nürnberg gear, and the inlet gear is a modified form of the Mees gear, and consists of a large piston valve mounted on the main valve stem and carried with it. Both gas and air are throttled by rotating this sleeve. Two 1,500-KW. direct-current generators, direct coupled to 38-inch by 54-inch twin tandem Westinghouse gas engines, are installed and nearly ready to operate at the same plant.

The Snow Steam Pump Company has under construction eight gas engine-driven blowing engines and four electric units. Six of these units go in one power house at the Duquesne Works of the Carnegie Steel Company. The electric units are all direct connected to 25-cycle, three-phase alternators rated at 2,000 KW. each, with liberal overload capacity. These twelve engines are duplicates. The gas cylinders are 42 inches by 54 inches and the air cylinders of the blowers 72 inches by 54 inches. While none of these engines are far enough advanced in the shop to make it possible to secure photographs, their characteristics and probable performance are foreshadowed in the engines of the same size built for the California Gas & Electric Company. These engines, which have been in successful operation for about a year, are direct coupled to 2,500-KW., 25-cycle, alternating-current generators. They operate in parallel with each other and also with the other parts of the power system, which consists of hydraulic turbines located in the mountains 150 miles distant, and a steam plant located on the opposite side of the city. The engines building for the United States Steel Corporation are to be operated with constant compression. Regulation is effected by a simple form of cut-off gear, which controls the quantity of gas admitted to the cylinder.



WESTINGHOUSE GAS-POWER BLOWING ENGINE AS INSTALLED AT THE EDGAR THOMSON WORKS OF THE CARNEGIE STEEL CO., PITTSBURGH

GAS POWER ELECTRIC UNIT OF 1,700 HORSE-POWER FOR CARNEGIE STEEL CO. WM. TOD CO., YOUNGSTOWN, OHIO

A distinctive feature of these engines is the location of both inlet and exhaust valves on a port cast at the side of the cylinder, an arrangement which allows the use of a very simple form of valve gear.

The Snow Company were the first builders of large gas engines in the United States, and the design here illustrated was developed by them in the natural gas fields, where large gas engine-driven compressors long ago became necessary to force the gas through the pipe lines leading from distant fields to populous distribution centres.

The engine illustrated on this page is one of a pair built for the Ohio works of the Carnegie Steel Company at Youngstown, Ohio, by the William Tod Company, of Youngstown. These engines are rated at 1,700 horse-power each and operate at 107 revolutions per minute. They are direct connected to 1,000-KW., 25-cycle, three-phase, alternating-current generators, and are of the four-cycle, double-acting type. The cylinders are 30 inches diameter by 42 inches stroke. A distinctive feature is the manner in which the stresses are transmitted to the main bed plates. The cylinders and water-jackets are integral and cast in halves, the main shell being bolted together with flanged joints, while the outer shell is fitted with expansion joints. The cylinders are not attached directly to the main bed plates nor to each other, but are carried by tie pieces and end supports in such a way that the barrels themselves are entirely free. The working stresses are transmitted through four forged-steel bolts extending the entire length of the cylinders and attaching directly to heavy bosses on the bed-plates.

The engine operates on the constant-compression system, and regu-

lation is effected by control of radial gridiron type gas inlet valves located in the upper section of the valve bonnet.

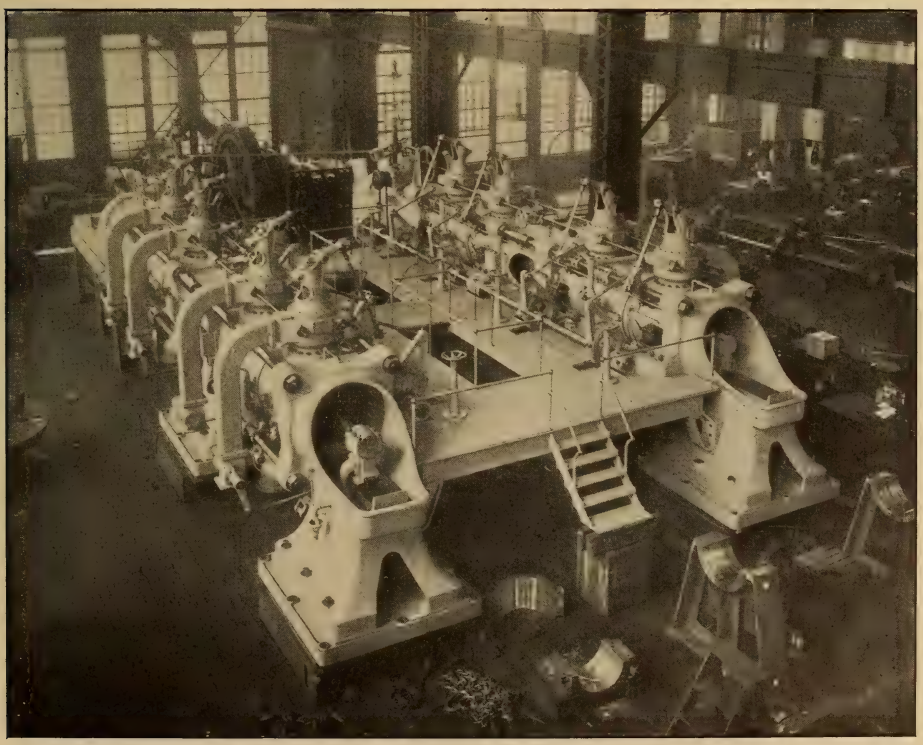
The Wm. Tod Company also have under construction four gas-driven blowing engines for the Ohio works. These engines will be similar in design to the electric units. They will have gas cylinders 42 inches by 60 inches and air cylinders 80 inches by 60 inches. The air cylinders are located ahead of the frame and driven by distance rods reaching forward from the main crosshead.

An Allis-Chalmers unit, consisting of a 2,000 horse-power gas engine direct connected to a 1,000-KW. generator, is shown among the illustrations. This particular unit is in regular service at the McKeesport plant of the National Tube Company. It is one of seven duplicate units of this size which the Allis-Chalmers Company are building for various blast furnace plants.

The engines are all twin tandem, with gas cylinders 32 inches by 42 inches. The generators, with the exception of the McKeesport unit, which is direct-current, are all 25-cycle, three-phase alternators built by the Allis-Chalmers Company. A large part of these units are now in regular service.

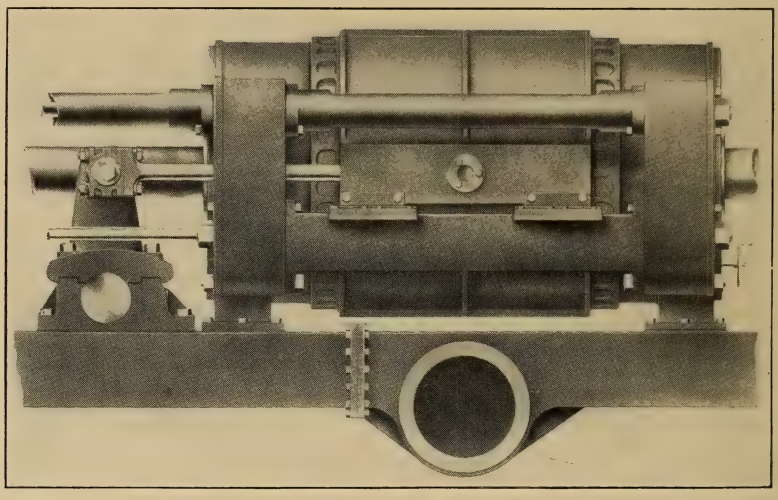
The Allis-Chalmers engines are all of the four-cycle type with double-acting cylinders arranged tandem, as shown. Regulation is effected by varying the lift of a poppet gas-inlet valve. The gear is very simple, and has proven extremely satisfactory. There are no special features in the design. It is simple and massive, designed for the hard usage it will receive.

In addition to the 1,000-KW. units and a few others of 500 horse-power, this company is building for blast furnace service thirty-six duplicate



REAR VIEW OF TOD ENGINES FOR CARNEGIE STEEL CO.

units of 4,500 horse-power each. Twelve of these are blowing engines for the Homestead works of the Carnegie Steel Company and for the Gary plant of the Indiana Steel Company, and twenty-four are direct connected to 2,000-KW. Allis-Chalmers 25-cycle, three phase alternators, seventeen of which form the complete installation in one of the Gary power houses, the others going to Homestead and the Illinois Steel Company. Several of these units are being erected in the field and about to go in service.

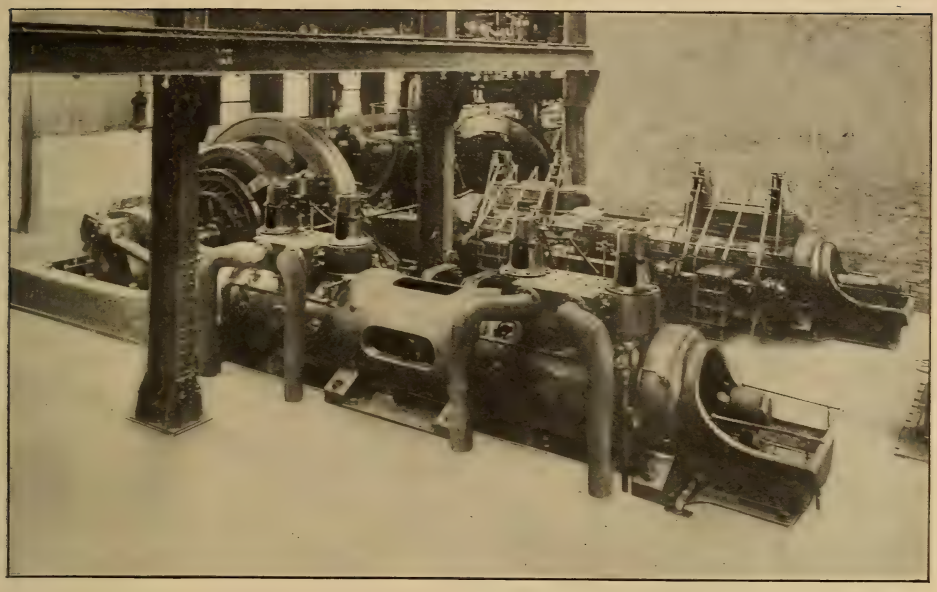


SLICK BLOWING CYLINDER, AS USED WITH GAS ENGINES

The gas cylinders of the electric units are 44 inches by 54 inches, and the engines operate at 83 revolutions per minute. With the exception of the air cylinders, the blowing engines are duplicates of the electric units. They will operate at 60 revolutions per minute, and have Slick type air cylinders 72 inches in diameter by 54 inches stroke.

The Slick type air cylinder here referred to was originated by Mr. E. E. Slick, chief engineer of the Carnegie Steel Company. The actual design in each case, however, is the work of the individual builder. The illustration shows the Slick air gear as designed by the Allis-Chalmers company. This gear is new, and deserves special mention. The air cylinder heads are stationary and held in place by distance pieces joining the heads to each other and to the engine frame. The cylinder barrel is separate from the head, and it is supported at each side on slides and is reciprocated. It is then in effect an inlet valve, and the circular ports at each end of the cylinder are the inlet ports. This system has exceedingly small clearance, leaves the entire area of the head free for the discharge valves, and allows so large a percentage of inlet area that the air cylinder is certain to fill without negative work even at very high speed. The discharge valves are automatic. These blowing tubs have proven satisfactory in service, and are peculiarly well fitted for use with the gas engine because of their efficiency at high speed.

This completes the list of gas engines installed or on order at the present time for blast furnace service. They have been enumerated with reference to the builder rather than to the plant, which was convenient, but unfortunate in this respect; it fails to show the magnitude of the individual plants, under ordinary circumstances, the plants at the Ohio works, or those at Home-

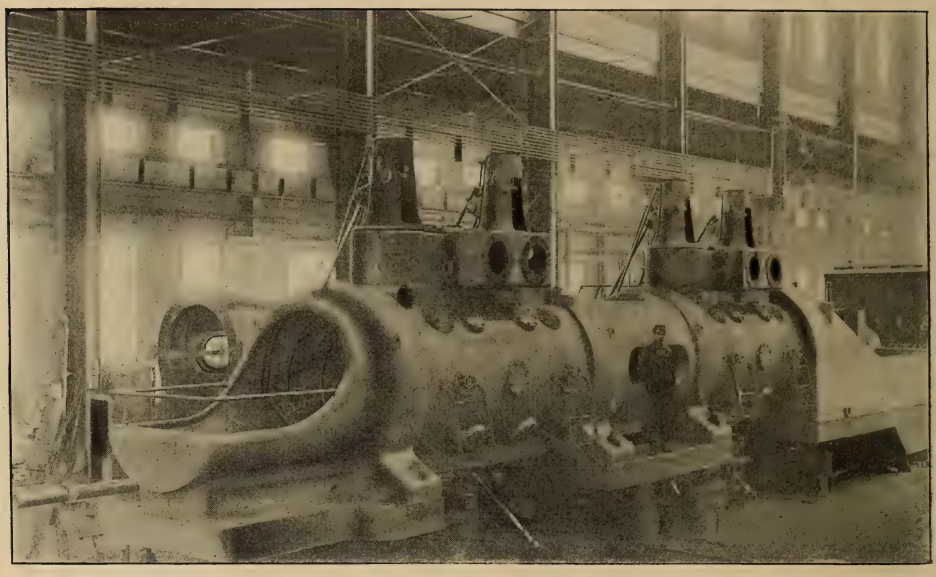


NATIONAL TUBE CO., MC KEESPORT WORKS. 2,000 HORSE-POWER ALLIS-CHALMERS GAS ENGINE

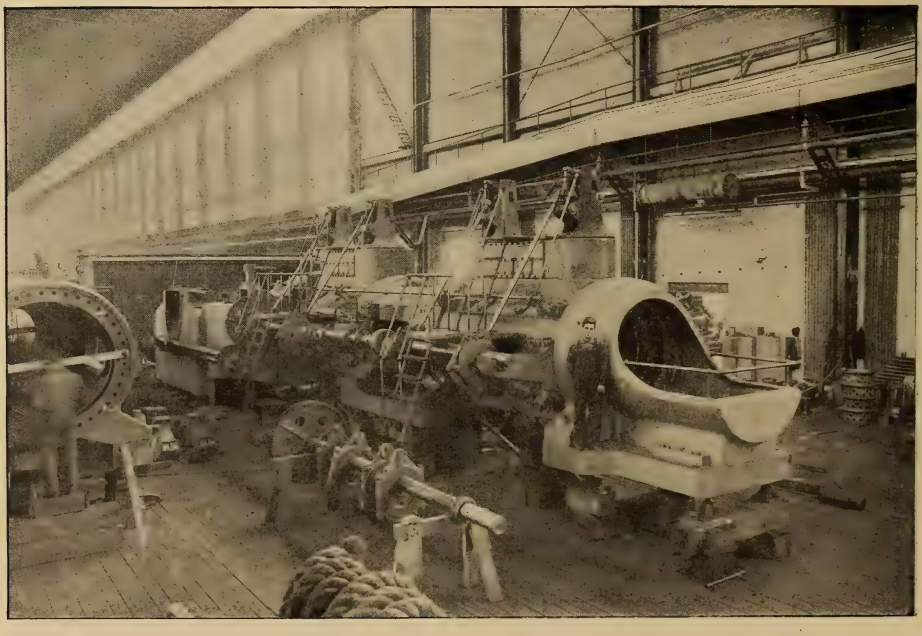
stead and Duquesne, representing, as they do, over $1,000,000 each for gas engines alone, would be considered great installations, but when considered in connection with the portion of the projected installation now building for the Gary plant of the Indiana Steel Company, they suffer by comparison.

The main electric power house at this plant, equipped complete with seventeen Allis-Chalmers engines and generators, is 125 feet wide and 1,000 feet long. There are, in addi-

NATIONAL TUBE WORKS, MC KEESPORT, PA. 2,000 HORSE-POWER ALLIS-CHALMERS GAS ENGINE



ALLIS-CHALMERS GAS ENGINE, 42-INCH BY 54-INCH. PARTIALLY ERECTED IN SHOP



ALLIS CHALMERS ENGINE, 4,500 HORSE-POWER, IN COURSE OF ERECTION

CALIFORNIA GAS AND ELECTRIC CO., SAN FRANCISCO. TWIN TANDEM GAS ENGINES. EACH PAIR 2,500 KILOWATTS. SNOW STEAM PUMP CO., BUFFALO, N. Y.

tion, two houses for blowers, 100 feet by 600 feet each, one with Westinghouse and one with Allis-Chalmers equipment, the total making for the portion of the plant so far under way a maximum horse-power of over 130,000, or, in round numbers, this partial installation is three times as large as the largest gas engine plant so far installed either in America or in Europe.

Interest naturally centres in the 4,500 horse-power units, of which a total of 64, or nearly 300,000 horse-power, are now in service or on order. Of these, six are in service, or will be in service during the present month, and the remainder are being delivered at the rate of an engine every fourteen days, or at a rate which will insure the delivery of all these engines during the coming year. Each engine and generator, or each blower, complete, weighs, in round numbers, 2,000,000 pounds, making a total for the sixty-four engines of 64,000 tons, and a shipment rate of two carloads daily.

From its infancy there has always been in the iron and steel industry something spectacular, an element that appealed to the imagination. The awe inspiring open-top furnace of the early days has gone, the spectacular flame from the Bessemer converter is waning, and now the magnitude of the industry, the fortunes wrested from what were once waste products, the miracles of electricity, of chromium, of nickel, of vanadium, the glimpse of wonders that are to be, these appeal to the imagination as powerfully as the physical manifestations of the earlier day appealed to the senses.

The gases which yesterday burned at the furnace top are turning the gas engines of to-day and generate the power which moulds the crude material into its finished state. They turn the rolls which form the columns and beams of the modern sky-scraper, and grind the slag, once wasted, to make the cement that binds the foundations on which they are to rest. For years the bee-hive oven at the mine has poured from its top a column of flame-shot smoke gorgeous in its tones of deepest red and brown. To-day in the by-product oven at the furnace the gases which vanished as flame and smoke yield tar, ammonia, and a gas which, used in the gas engine, makes the furnace a power reducer far beyond its immediate needs, and will make it indeed a centre of power so great as to be comparable only with the great water-powers; and when by these manifold economies the finished product has been cheapened, and when by changes in composition a lesser weight shall give equal strength, who will say to what new uses this product may be put, or who will predict the proportions to which this industry will have attained even in another decade? And in the glory that is, and is yet to be, the gas engine has no insignificant part; except for the economies effected by its use, a great part of this development is hardly possible, and while prosaic masses of iron and steel can never stir the mind of the layman as did the mighty tongue of flame which marked the location of the early furnace, nevertheless the gas engine installation at any furnace will, in a very few years, be a wonderful feature, and something of romance may linger in the thought that the elements which are combined at furnace and oven top merely to form a wondrous vision for the eye, are to-day combining unseen, in closer, hotter embrace within the engine cylinder, to produce the power which man will turn to useful ends in all departments of industry.

BY-PRODUCT RECOVERY GAS PRODUCER PLANTS

By H. A. Humphrey, M. Inst. M. E., M. I. E. E.

There is an increasing tendency towards the lessening of wastes in industrial operations, and to the corresponding feature of the utilization of products which, being formerly thrown away, are now dignified with the title of "by-products." Nearly every process of manufacture results in a number of products, and formerly the principal one of these formed the whole object of the effort, the minor effects being wholly neglected. In the various departments of the gas industry the recovery of by-products has taken an important part in recent developments. Fuel and power gas itself is a by-product of important metallurgical operations, as is seen in the utilization of the formerly wasted gases of blast furnaces and coke ovens, while both coke ovens and gas-producers are now largely equipped with apparatus for saving the valuable chemical products which formerly went to waste. Mr. Humphrey treats of one of the most important departments of this side of the gas question, the recovery of such a valuable commercial article as sulphate of ammonia from the wastes of the gas producer, showing the success which has been attained by Dr. Ludwig Mond and his associates.—The Editor.

WITH sulphate of ammonia at £12 per ton, and with a steadily increasing demand for this material, there is a veritable gold mine hidden away in the nitrogen contained in common bituminous coal or slack. The ordinary cheap fuel used in by-product recovery gas producers yields about 90 pounds of sulphate of ammonia, having a value of nine shillings for every ton of coal gasified. It takes less than half this amount to work the additional ammonia-recovery plant and to provide the necessary material, labour, repairs, etc., and to evaporate the sulphate solution in order to obtain the solid sulphate; but allowing one-half for this purpose, there is a net profit of 4s. 6d. per ton of coal gasified. Herein lies one of the great attractions for this type of plant, and the additional apparatus over and above the ordinary bituminous fuel producer plant is neither extensive nor complicated.

No one knows precisely the form in which the nitrogen exists in the coal, but analysis shows that about 1.3 per cent. by weight of this constituent is an average figure for the kind of fuel used in ammonia recovery gas plants. All of this nitrogen cannot be extracted in the desired form, but about 70 per cent. of it is recoverable if proper precautions are taken. In ordinary producers, such as one finds in most of the iron and steel works, generating gas for furnace purposes, very little ammonia is to be found in the gas, for the simple reason that the temperature at which these producers are worked destroys the ammonia, and the great difference between such producers and the producer designed with the object of recovering ammonia is seen in the temperature at which the gas leaves the producer. In the ordinary producer this temperature may be anything between 700 and 1,000 degs. C., while in the by-product producer it is about 450 degs. C. It has long been known that the most practical way to increase the yield of ammonia is to introduce along with the air blast large quantities of steam. Exhaustive experiments have shown that the ammonia yield continually increases with the increase of the steam, untill a point is reached corresponding to about $2\frac{1}{4}$ tons of steam entering the producer for every one ton of coal gasified, but the exact amount depends somewhat on the nature of the fuel. This may seem a very big quantity, and one of the great problems in the design of by-product producer plants is presented by the question, "How can this large amount of steam be economically raised and its sensible and latent heat profitably utilized?"

Twenty years ago Dr. L. Mond, F. R. S., was engaged in solving this problem, and in 1889, when the president of the Chemical Society, he gave the details of the very successful and practical solution at which he had arrived. He invented not only a suitable gas producer, but a complete system of working, in which the sensible and latent heat of the large volume of gas and steam leaving the producer was saved and transferred back to the producer again, reappearing as heat in the air and steam entering the producer. Although the Mond plant has been frequently described and is widely known, yet a brief description will not be out of place, as it is typical of all other ammonia recovery producer plants. The explanation will be made clear by a reference to the diagram, Fig. 1. Cold air from the blowers, drawn from the surrounding atmosphere, has to be enriched with a large volume of steam and heated to a considerable temperature before it may be considered a suitable blast for an ammonia-recovery producer. The amount of air necessary in the gasification of one ton of coal varies with the analysis of the coal itself; but taking an average bituminous slack containing 68 to 69 per cent. of total carbon tested on the dry sample, the air required weighs 2½ tons, and to give the best results this air should be saturated with steam at a temperature of about 85 degs. C. This means that the air must enter the producer carrying with it 2.17 tons of steam. Turning to the diagram, we see that the cold air is forced by means of the blower *B* through an air-heating tower *A*, where it meets a stream of hot water flowing down the tower over a number of tiles, which spread the water and give it a very large surface of contact. This raises the temperature of the air and saturates it with water vapour, so that by this means alone 0.84 tons of steam have been added to the blast. There remains 1⅓ tons of steam to be added, and this is generally furnished from the exhaust steam from the steam engines, but can be produced by utilizing the hot exhaust gases leaving the gas engines wherever the whole of the Mond gas is used for the production of power in such engines. Only low-pressure steam is required, and any other source of supply will do; for instance, the steam raised from the evaporation of brine, where salt is produced in enclosed pans, has been most successfully employed. In any case, the steam added should be sufficient to bring up the temperature of the blast to 85 degs. C., with a corresponding saturation. The mixed steam and air now pass through the tabular regenerators, and then through the air-jacket of the producer to the grate bars, and by abstracting heat from the outgoing gases leaving the producer and traversing the regenerator in the opposite direction the blast temperature is raised to over 250 degs. C. The details of the producer itself need not be here gone into, but we will follow the course of the gas leaving it and note that this gas, after passing trough the tabular regenerator, enters a mechanical washer consisting of a long wrought-iron box with a lute running the whole of its length on one side and containing water up to a certain level. Revolving dashers are so placed that they scoop up this water and fill the whole box with finely divided spray. The hot and dirty gases entering this washer are subject to the violent action of this spray, which cools and cleans the gases before they pass to the towers, to be described. No other form of apparatus has been found so successful for removing the coal dust and tar carried over by the gas, but this is not the only, or even the most important, function of the washer. It might really be called a gas saturator, for in it the sensible heat of the gas, available by reducing its temperature from nearly 300 degs. to say 85 degs. C., is utilized to generate steam, which is

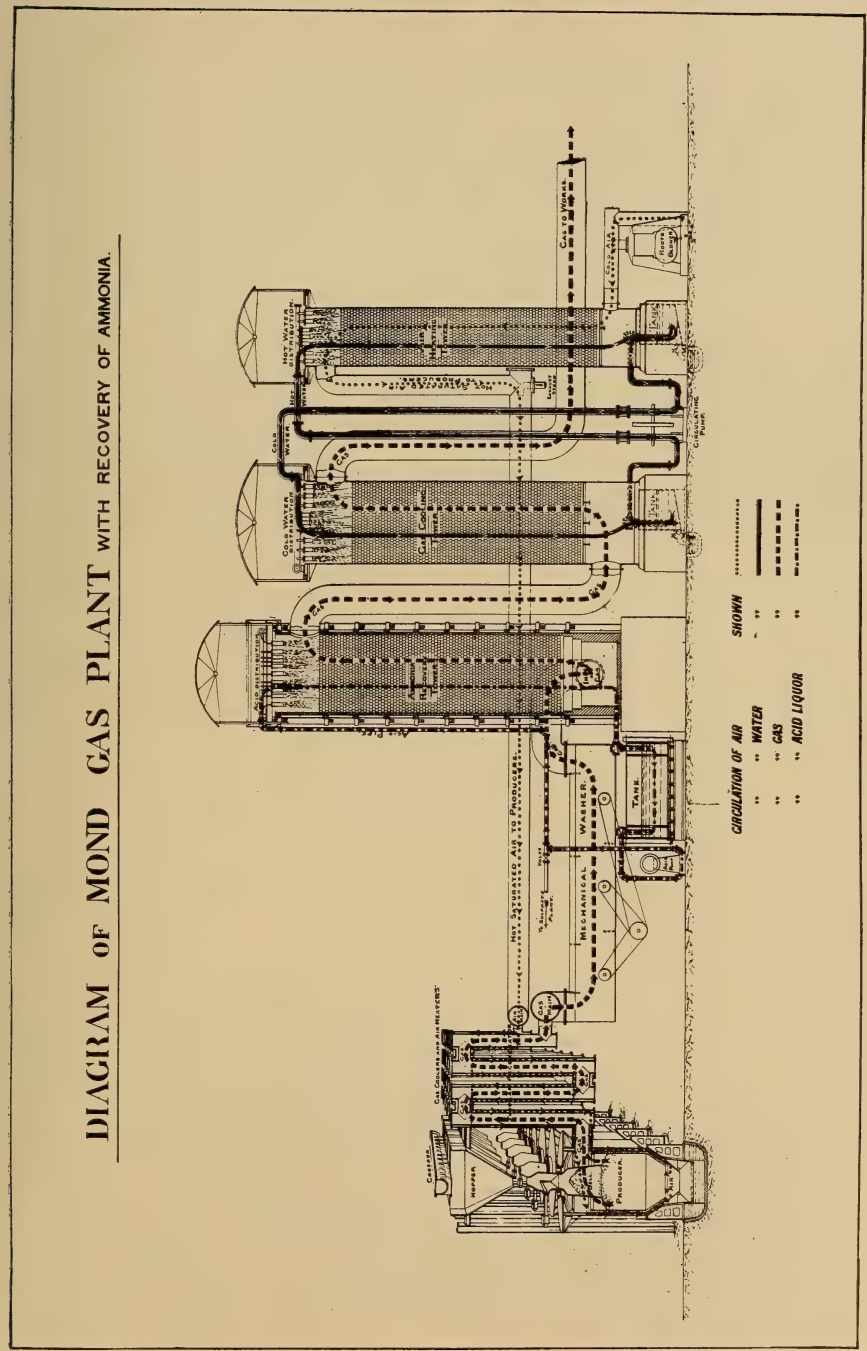


FIG. 1.—SECTIONAL DIAGRAM, SHOWING GENERAL ARRANGEMENT OF MOND BY-PRODUCT RECOVERY GAS PLANT

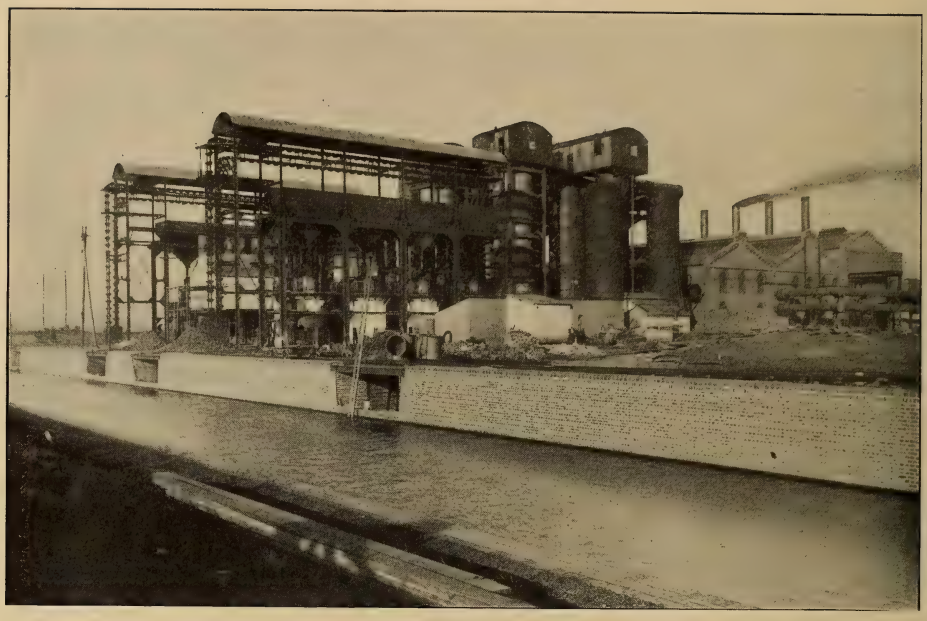


FIG. 2.—SOUTH STAFFORDSHIRE MOND PLANT, CAPABLE OF GASIFYING 160 TONS OF COAL PER DAY

carried forward by the flow of the gas.

Now comes the ammonia-recovery tower, in which the strong chemical affinity existing between ammonia and sulphuric acid is utilized to bring about the combination of the two to form sulphate of ammonia. The action is so perfect that very little ammonia escapes along with the gas leaving the top of the tower, and the free acid in the circulating liquor, which traverses the tower from top to bottom in the opposite direction to the gas, need not be more than 4 per cent. To make the process continuous, fresh acid has to be added as fast as it is neutralized by the ammonia, and some of the circulating liquor is constantly abstracted, containing the sulphate of ammonia, which has finally to be eliminated in the solid form by boiling down. As sulphuric acid will attack iron, the ammonia recovery tower must be made in lead or stone, and generally the former is preferred. Also, the filling of the tower must be made of acid-proof material.

Continuing its flow, as denoted by the arrows in the diagram, the gas now enters at the bottom of the gas-cooling tower, and is cooled by means of a shower of cold water passing down this tower. This water is the same as was used in the air-heating tower; in fact, the water circulation is in a closed circuit. When it leaves the air-heating tower it is cold, having given up its heat to the air blast; but in the gas-cooling tower it enters cold and leaves hot, being heated by the hot gas, but it is also the recipient of the latent heat liberated by the condensation of the bulk of the steam which had been carried into the tower by the producer gas. Thus enormous quantities of heat are transferred directly from the hot circulating water to the cold air and from the hot gas to the cold water, and this regeneration by means of water circulation, coupled with the further heat interchange in the tubular regenerators, constitutes the very efficient system referred to and thus renders the Mond gas plant an economical one to work.

In a large illuminating gas works the by-products recovered from the distillation of the coal are frequently numerous, for, in addition to sulphate

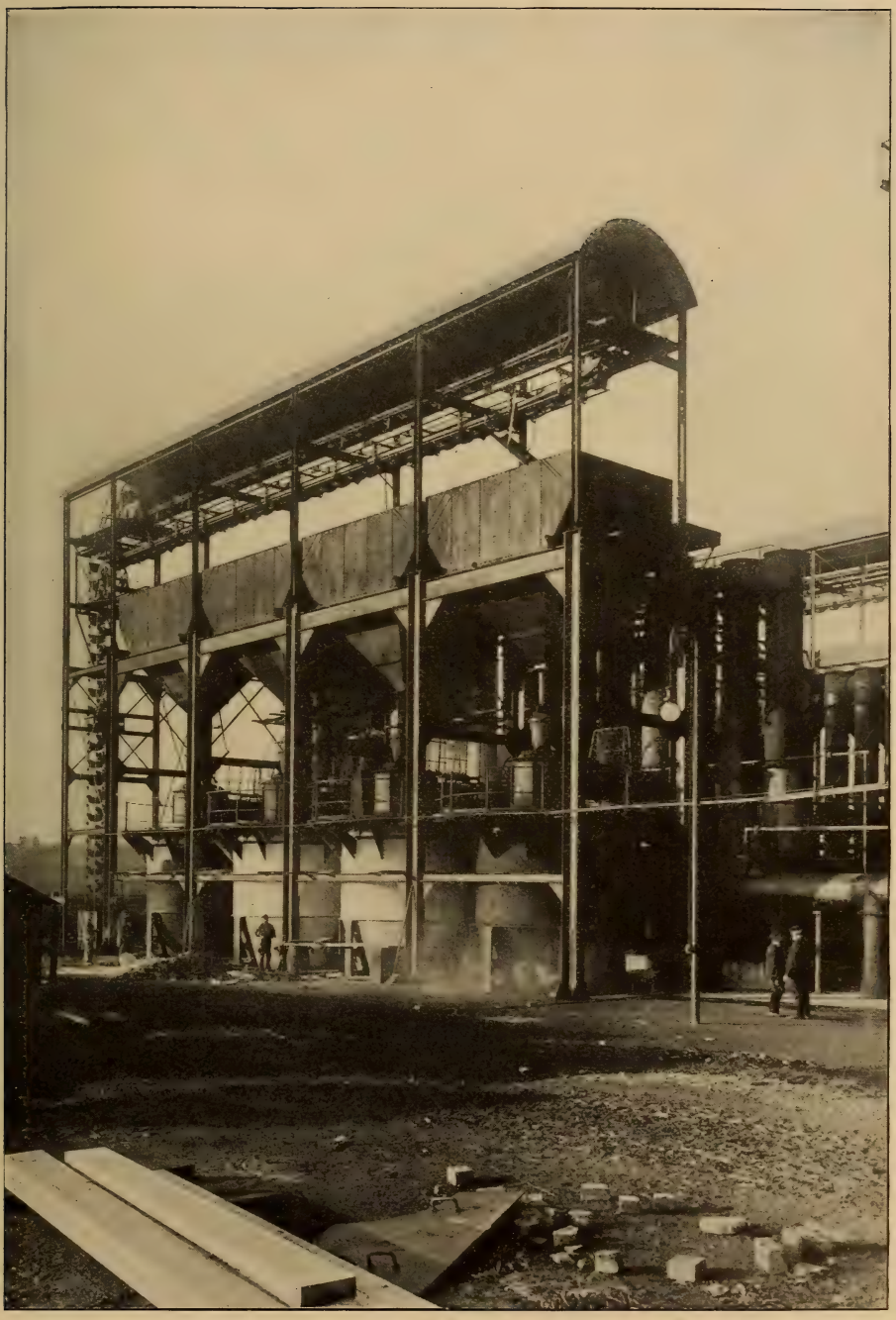


FIG. 3.—SOUTH STAFFORDSHIRE GAS PLANT, SHOWING THE PRODUCERS

of ammonia, coke, pitch, tar, heavy and light oils, aniline dyes and other derivatives of tar are recovered. In gas producer plants about 90 pounds of sulphate of ammonia are recovered per ton of coal, which is almost four times as much as is obtained from the lighting-gas works; but the other by-products are less numerous, as the quality of the tar differs in its nature from the gas works tar, although capable of yielding a good pitch and considerable quantities of creosote oil. Speaking generally, the owner of a by-product producer plant is satisfied in selling the sulphate of ammonia, and, in addition, the pitch and tar produced, and does not trouble to distil the latter, although, when the plant is large enough, there is a good profit to be obtained in connection with the better quality of pitch and the creosote oil resulting from further treatment.

FIG. 4.—VIEW IN PUMP AND MACHINERY HOUSE, SHOWING BLOWERS FOR AIR BLAST, AND PUMPS FOR WATER AND ACID CIRCULATION

All coal is not equally suitable for use in by-product gas producers. Anthracite and hard steam coal are too expensive on the one hand, and do not contain enough nitrogen to make ammonia recovery profitable. Bituminous coals containing 1.3 per cent. of nitrogen will generally yield about 90 pounds of sulphate of ammonia per ton of coal, as already stated; but this figure is liable to vary, and of two coals containing the same amount of carbon and nitrogen, respectively, more ammonia is recoverable from that coal in which the most carbon exists in the fixed form as compared with the volatile form. Unfortunately, a number of bituminous coals found in Great Britain, which are rich in nitrogen, also possess the unfavourable quality of readily melting and caking, and in selecting a coal for producer work this property has to be considered, as the coal which readily cakes together is more difficult to work in a producer and needs more poking and labour. To overcome this difficulty Mr. Talbot, of steel furnace fame, invented a mechanical stirrer, which is placed inside the producer and driven by power. It has a rotary motion, and, in addition, a vertical motion, and those portions which are subjected to the heat of the producer are internally water-cooled. This apparatus keeps the whole of the fuel properly stirred, and so permits of the use of a more caking

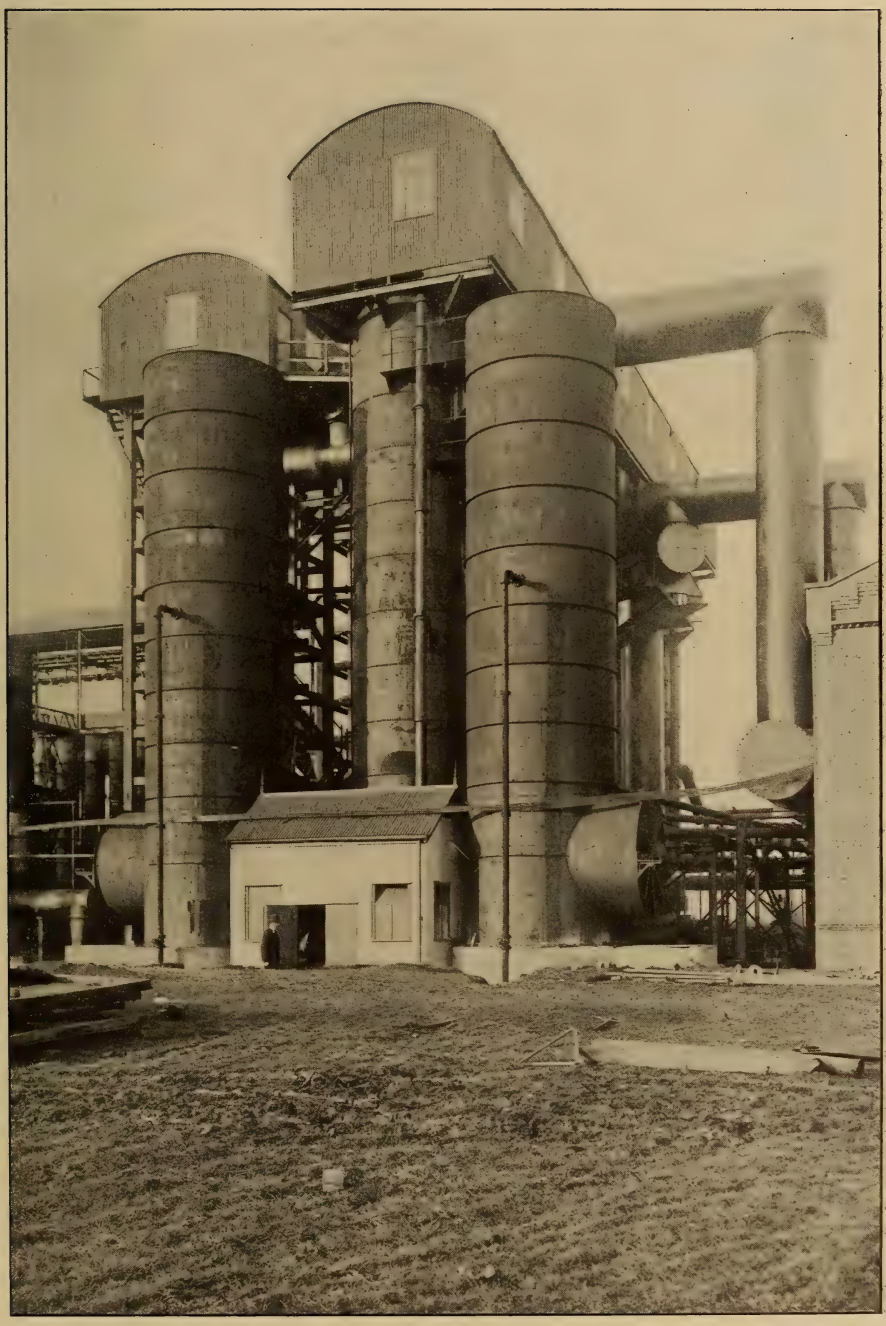


FIG. 5.—GROUP OF TOWERS WITH INTERCHANGEABLE CONNECTIONS DEALING WITH GAS FOR 30,000 HORSE-POWER. THE POWER GAS CORPORATION, LTD., LONDON

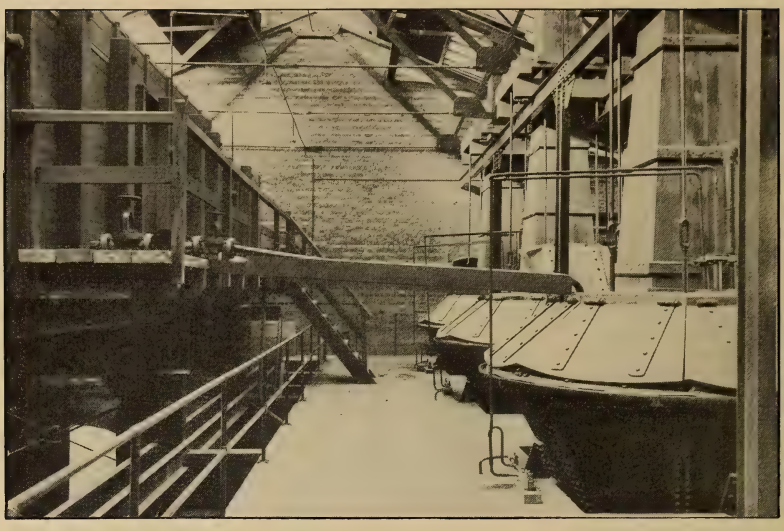


FIG. 6.—SULPHATE OF AMMONIA PLANT. THE POWER GAS CORPORATION, LTD., LONDON

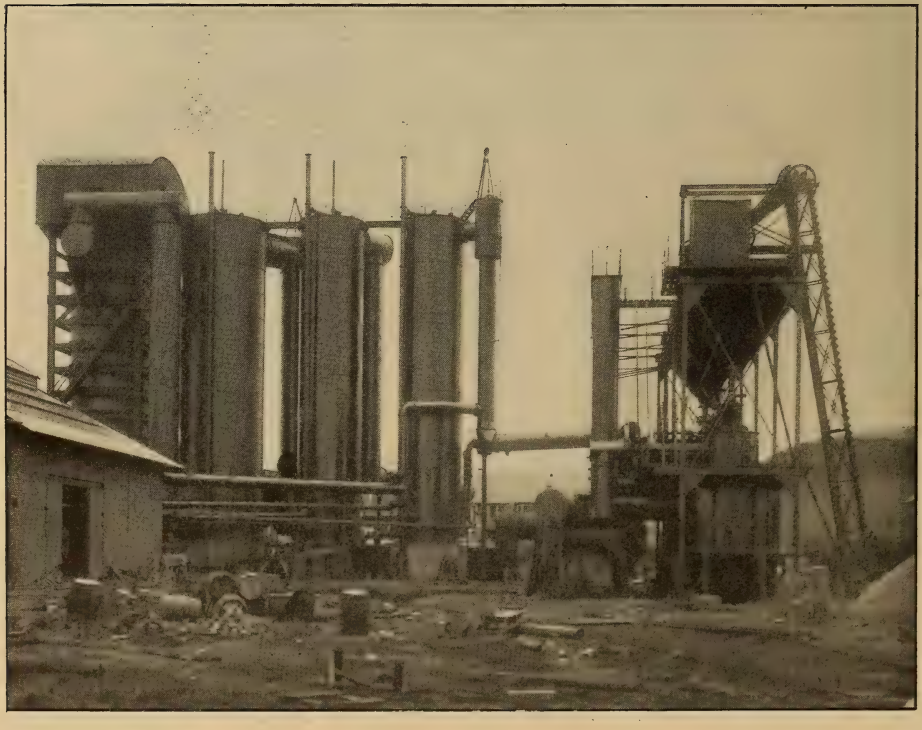


FIG. 7.—MOND PLANT, CAPACITY 160 TONS OF COAL PER DAY

quality of fuel, but in most localities cheap coal can be obtained which does not require the use of such a mechanical apparatus.

The introduction of large volumes of steam into the producer along with the blast not only preserves the ammonia from destruction, and so renders a very large recovery possible, but it also serves to prevent the formation of clinkers. Mond producers can be worked for months on end without even a sign of any heavy clinkering in the ashes. This is important because it enables the producers to be run continuously, and makes the withdrawal of the ashes from the water-lute a simple process. Further, the quality of the gas produced is much more uniform when the large amount of steam is introduced, for two principal reasons,—in the first place, by saturating the air at a definite temperature, an exact ratio between the amount of air and steam entering the producer is maintained; and, secondly, the temperature of combustion in the producer is so much more under control. As might be expected, the steam plays a very important part as regards quality of gas produced, and from a producer worked in the manner described one may expect gas containing 11 to 12 per cent. of CO, 27 to 29 per cent. of hydrogen, and 2 to 3 per cent. of CH_4. These are the combustible constituents, and the inert gases will consist of 15 to 16 per cent. of CO_2, and about 42 per cent. of nitrogen. If the quantity of steam entering the producer is diminished, the amount of hydrogen in the gas gets less and the amount of carbon monoxide grows larger; but the heating value, which is about 150 B. T. U. per cubic foot, remains fairly constant within the working limits which are suitable for recovery producers. The

FIG. 8.—MOND PLANT WITH SIX PRODUCERS FOR 120 TONS OF COAL PER DAY. SALT UNION, LTD.

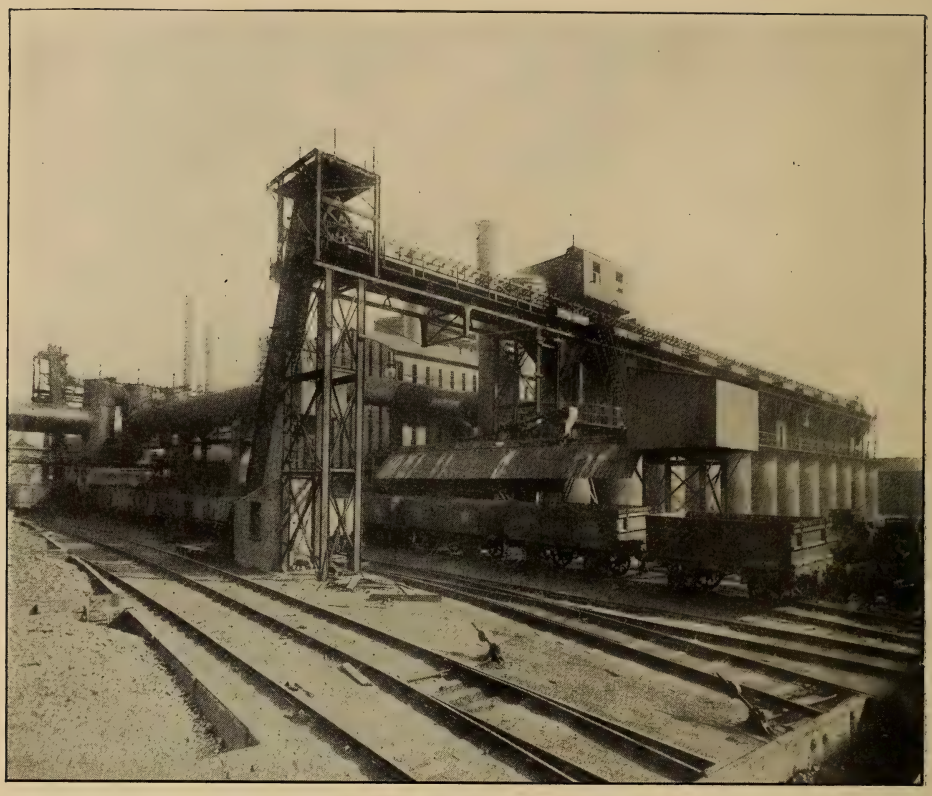


FIG. 9.—GAS-POWER AND BY-PRODUCTS CO., LTD., GLASGOW. PLANT CAPABLE OF GASIFYING 500 TONS OF COAL PER DAY

total volume of gas made from a ton of coal varies with the carbon contents of the coal, and ranges from 125,000 to 150,000 cubic feet, measured at 15 degs. C.

It is worth while to investigate a little closer the difference between the quality of the gas from a by-product recovery producer and that from an ordinary gas producer, in which no recovery is attempted. In the former we burn rather more than half the carbon of the coal to CO_2, the balance of the carbon being in the form of a combustible, and therefore useful, gas. But the heat liberated in the burning of this carbon has been utilized to decompose more than half a ton of steam in the producer, thus giving rise to the very large amount of hydrogen gas mentioned in the preceding paragraph. The resulting gas has, therefore, for each cubic foot as high a thermal value as if less of the carbon of the coal had been completely burnt to CO_2, and the total heat value of the gas derived from a ton of coal is not diminished by this system of working, and represents over 80 per cent. of the heat value of the coal gasified.

A few of the plants constructed by the Power Gas Corporation, which owns the Mond patents, are here illustrated. Fig. 2 gives a view of the South Staffordshire Mond gas plant, capable of gasifying 160 tons of coal per day. The buildings shown on the right hand side of the illustration contain the machinery for circulating the hot and cold water and acid liquor, and the plant for further cleaning and compressing the gas, together with the boilers for supplying the necessary steam. The

steam raised under pressure passes through the gas compressors, water pumps, etc., which act as reducing valves, and is then, as exhaust steam, mixed with the blast to provide the additional steam necessary for working the producer. This plant is specially interesting as being the first of its kind sanctioned by Parliament for the production and distribution of Mond gas over a large industrial area of 120 square miles. At present the gas is distributed from the station at 5 pounds per square inch pressure, and is used for all kinds of purposes, as, in addition to some thousands of horse-power of gas engines, there are numerous kinds of furnaces fired by this gas. The plant has been continuously at work, day and night, for two and one-half years without a single stoppage for any purpose whatever. Fig. 3 shows a nearer view of one-half of the producer plant, and Fig. 4 is a general view taken inside the pump and machinery house, showing the blowers for supplying the air blast and the pumps for circulating the water and acid liquor. Fig. 5 is a group of towers arranged with interchangeable connections, capable of dealing with the gas for 30,000 horse-power, and in Fig. 6 is shown a sulphate of ammonia plant, where the sulphate liquor obtained from the ammonia recovery tower is stored in the tanks shown on the left and evaporated in the vessels shown on the right, these being lead-lined vessels containing large lead steam coils. Fig. 7 shows another Mond plant capable of gasifying 160 tons of coal per day, and Fig. 8 shows a six-producer Mond plant erected at the works of the Salt Union, Limited, for gasifying 120 tons of coal per day.

Messrs. Crossley Bros. have for

FIG. 10.—THE GAS-POWER AND BY-PRODUCT CO., LTD., GLASGOW. PLANT FOR GASIFYING 250 TONS OF FUEL PER DAY

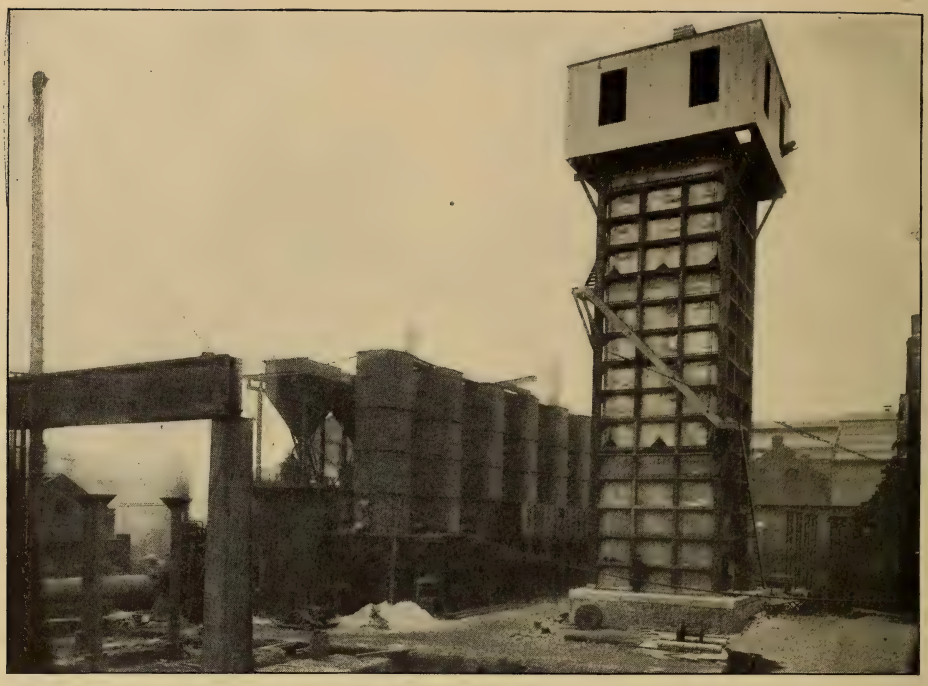


FIG. 11.—A SMALL PLANT, CAPACITY 150 TONS PER DAY. SHOWING AMMONIA RECOVERY TOWER

some years been making a producer suitable for use with bituminous fuel, and have recently erected at their works in Openshaw a gas plant of 2,500 horse-power capacity, fitted with the necessary apparatus for recovering the ammonia.

The Gas Power and By-Products Company, Ltd., are also makers of the type of plant under consideration, and, by the end of the year, plants on their system, capable of gasifying over 1,000 tons of fuel per day, will be at work in some of the principal steel works of the country. Fig. 9 shows one of their plants capable of gasifying 500 tons per day, while Fig. 10 is a plant of half the capacity just mentioned, and another smaller plant, for 150 tons per day, is shown in Fig. 11, which gives a good view of the ammonia recovery tower. The photographs reproduced in Figs. 10 and 11 were taken during the construction of the plants. The success of the company in utilizing the gas from their plants for the various processes in connection with steel works demonstrates that a cool, washed gas, containing a large proportion of hydrogen, is suitable for practically all kinds of metallurgical work. So long ago as 1895 Mr. J. H. Darby, of Brymbo, read a paper before the Iron and Steel Institute demonstrating that Mond gas in an open-hearth Siemens furnace gave steel of excellent quality, but until recently steel makers have been somewhat slow in applying this kind of gas to replace the ordinary gas generated from the producers working with much less steam in the blast. The Gas Power and By-Products Company state that their experience has proved over a long period that the use of by-product recovery gas producers constructed by them has resulted in a saving which may amount to as much as three shillings per ton of finished steel.

As the other pages in this number of CASSIER'S MAGAZINE deal fully with the subject of gas engines, a few words might be said about the use of Mond gas, and

similar producer gases containing a large percentage of hydrogen, in gas engines. When the causes of pre-ignition were largely unknown, troubles in this direction were frequently ascribed to the large percentage of hydrogen present in the lighting gas, coke oven gas, or Mond gas used, and it was supposed that a high initial compression was prohibitive when these kinds of gases were employed. Such troubles were eventually traced to the design of the engine and to the existence of rough surfaces, sharp corners, etc., in the combustion chamber or passages, and now engines of modern design work as well with Mond gas as with gas of a similar heating value but containing less hydrogen and more carbon monoxide. The author has seen an engine working with Mond gas compressed to 200 pounds per square inch before explosion, and giving no trouble whatever from pre-ignition. Compression pressures of 130 to 160 pounds per square inch are now quite usual with this gas, and its use for power purposes is rapidly extending. The Mond plants sold by the Power Gas Corporation, Limited, have a capacity of 270,000 horse-power, and a large proportion of this gas is used in gas engines. Messrs. Crossley Bros. have constructed nearly 200,000 horse-power in gas plants, about one-half of which work with producers using bituminous fuels, and, as already stated, their latest plant of 2,500 horse-power is also fitted for ammonia recovery. So surely as the internal combustion engine is the engine of the future, the by-product recovery gas producer is the producer of the future, and will be installed wherever the power is sufficient to warrant the erection of this type of plant. We are only on the threshold of developments in this direction, compared with which the work accomplished up to the present will, in the near future, seem insignificant.

THE UTILIZATION OF THE WASTE GASES OF BLAST FURNACES AND OF COKE OVENS IN METALLURGICAL WORKS

By Leon Greiner

It has already been shown elsewhere in this issue, by Mr. Thwaite, the originator of the direct use of furnace gases in the internal-combustion engine, that there is here an important source of motive power, one which should render iron-producing centers also points from which the distribution of electrical energy should be effected. M. Greiner adds to the article of Mr. Thwaite the results of a ripe experience at the establishment of which he is the chief engineer, the great John Cockerill Works at Seraing, near Liége, Belgium, the place where the large gas engine was first put into continuous practical service for the development of power from the waste gases of the blast furnace, and where it has altogether ousted the steam engine as a source of motive power. M. Greiner speaks whereof he knows, and his results are both academic and practical, and hence of double value to the mechanical and metallurgical engineer.—The Editor.

I

INDUSTRIAL prosperity is intimately connected with the conditions surrounding the production of coal. The cost of producing coal, however, increases continually, because the principal element in its cost is the price of labor. It is because of the successive increases in wages, as well as the reduction in the number of hours of labor, that the recent advances in the price of coal are due. This situation is one which must continue to become aggravated, since the supply of coal is a diminishing quantity, and the difficulty of its extraction is increasing.

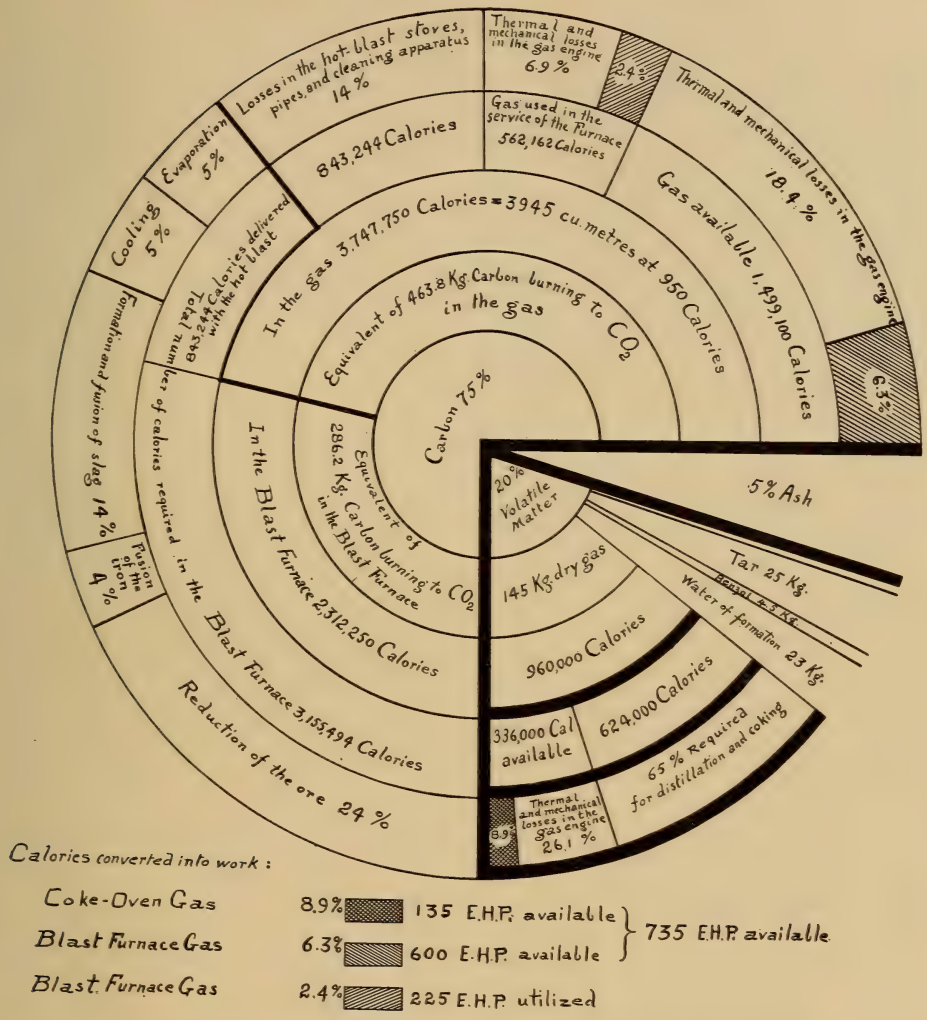
There is a general realization in all departments of industry that economy is necessary in the use of the precious combustible, and in this respect the metallurgical industries are especially interested, since the cost of fuel occupies such an important place in the net cost of its products.

In the iron and steel industries coal is used under two different forms; as coke, in the reduction of ore and the fusion of the pig iron, and as a fuel for the boilers and heating furnaces in the mills in which the pig iron is converted into the finished product of steel. Economy in the use of coke depends upon the uniformity in the operation of the blast furnace, and the proper maintenance and operation of the hot-blast stoves. There is a limit below which the consumption of coke rarely descends, and in the case of furnaces operating under the best conditions there is used not less than one ton of coke for every ton of pig iron produced. The cost of coke, therefore, is about 35 to 40 per cent. of the net cost of the iron produced.

The question of fuel economy in the steel works and rolling mill depends upon the method of operation, since continuous operation enables the otherwise large losses by cooling to be avoided. It is also materially influenced by the degree of perfection of the steam engines employed. Much progress has been made in this direction in the last few years, and the thermal efficiency of modern steam engines and boilers has been very materially improved. The cost of fuel, however, is not less than 700 to 900 pounds of coal per ton of finished product.

Although it is thus difficult to reduce the cost of coke consumed in the blast furnace, or to lower the quantity of steam required per horsepower in the rolling mill and the blowing engines, it is possible, in these metallurgical operations, to realize an indirect economy by the utilization of products in the coal, which, until very recently, have been entirely lost.

It is for these reasons that the use of the regenerative by-product coke oven has become an essential in mod-


Losses in the hot-blast stoves, pipes, and cleaning apparatus 14 %
Thermal and mechanical losses in the gas engine 6.9 %
2.4 %
Thermal and mechanical losses in the gas engine 18.4 %
Evaporation 5 %
843,244 Calories
Gas used in the service of the Furnace 562,162 Calories
Gas available 1,499,100 Calories
6.3 %
Cooling 5 %
Total number of Calories delivered with the hot blast 843,244 Calories
In the gas 3,747,750 Calories = 3945 cu. metres at 950 Calories
Equivalent of 463.8 Kg. Carbon burning to CO_2 in the gas
Carbon 75 %
20 % Volatile Matter
5 % Ash
Tar 25 Kg.
Benzol 2.3 Kg.
Water of formation 23 Kg.
145 Kg. dry gas
960,000 Calories
624,000 Calories
336,000 Cal available
65 % Required for distillation and coking
Thermal and mechanical losses in the gas engine 26.1 %
2.9
Number of calories required in the Blast Furnace 2,312,250 Calories
In the Blast Furnace 3,155,494 Calories
Equivalent of 286.2 Kg. Carbon burning to CO_2 in the Blast Furnace
Reduction of the ore 24 %
Combustion of fusion of slag 14 %
Fusion of the iron 4 %
Calories converted into work :
Coke-Oven Gas
8.9 % 135 E.H.P. available
Blast Furnace Gas
6.3 % 600 E.H.P. available
735 E.H.P. available
Blast Furnace Gas
2.4 % 225 E.H.P. utilized

TOTAL PRODUCTION OF A TON OF COAL IN THE COKE OVEN AND BLAST FURNACE

ern installations, and that the utilization of the combustible gas produced in excess, both in such ovens and in the blast furnace, is rendering them centres for the production of motive power.

Such a utilization of coal includes three distinct industries: 1. The separation of chemical products, such as sulphate of ammonia, tar and benzol; 2, the manufacture of pig iron; and, 3, the generation of electricity.

It is a matter of especial interest to note that in following the various stages of the utilization of coal, from the time it enters the coke oven until it is wholly consumed in the blast furnace, it is possible to supply to the gas engine energy sufficient to enable an important amount of power to be developed. After a preliminary crushing the coal is charged into the coke oven, where it is distilled and transformed into coke. This distillation causes the disengagement of gas, of which the value depends upon the quantity of volatile material contained in the combustible. This gas is withdrawn by exhausters and caused to traverse the various de-

vices for condensation and regeneration, the tar being deposited, and the benzol and ammonia separated. This last product, transformed into sulphate of ammonia by a special treatment, is utilized in agriculture as a fertilizer. Deprived of these products, which already represent an important value, the gas contains only hydrogen, carbon, monoxide and methane.

A portion of this gas is diverted into the flues of the coke oven, where its combustion acts to effect the distillation and coking of the coal, and the balance is available for the production of motive power, either by being burned under steam boilers, or by direct use in the cylinders of internal-combustion engines. So much for the use of regenerative by-product coke ovens.

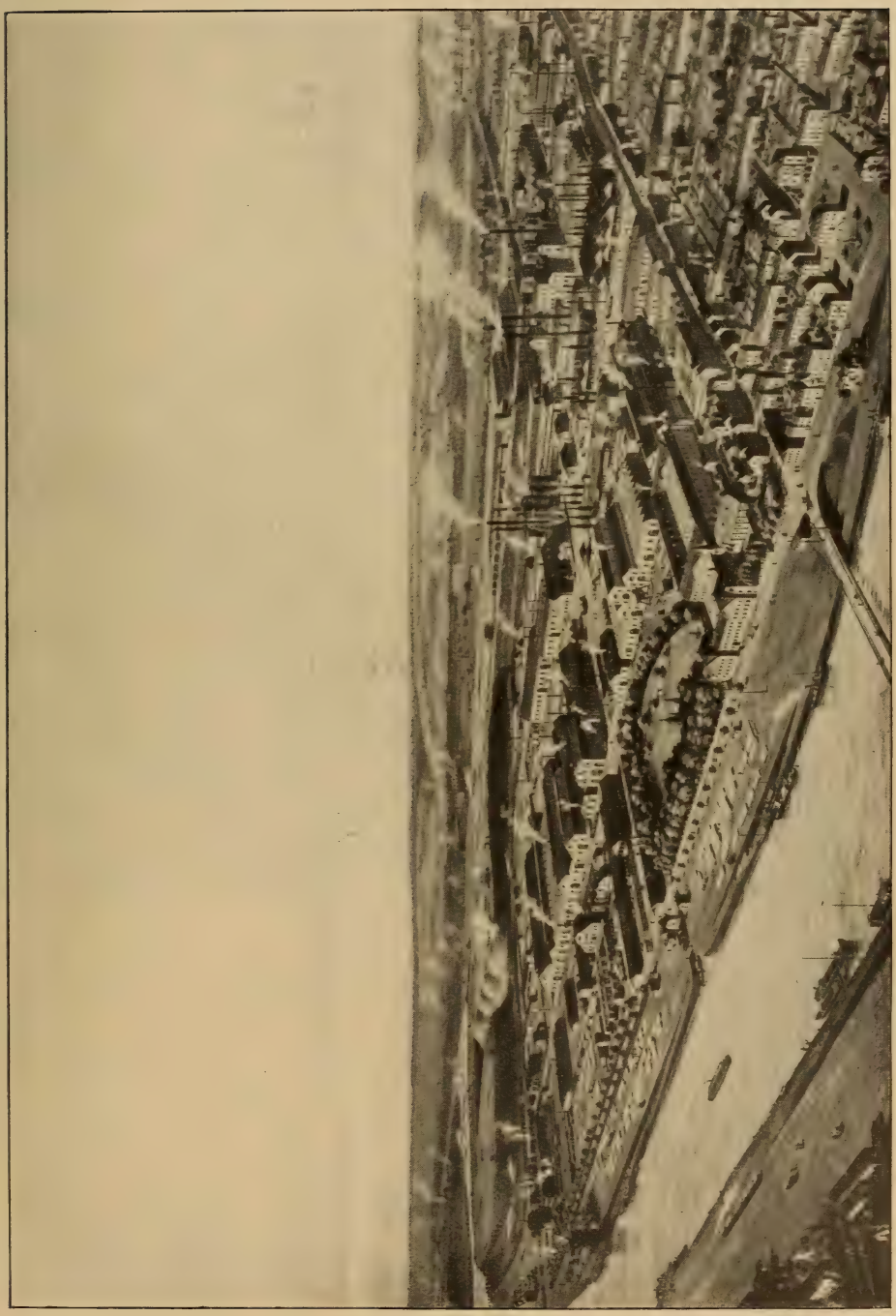
Let us now see what becomes of the coke when it is delivered into the top of the blast furnace, together with the iron ore.

One portion of the carbon is necessary for the reduction of the ore and the fusion of the iron, as well as for the formation and fusion of the slag; the balance appears as CO in the combustible gas which escapes from the furnace. A certain amount of this gas is utilized in raising the temperature of the blast. The remainder of the gas is capable, if used in gas engines, of furnishing an amount of power much greater than is necessary for the various requirements of the blast furnace: the blowing engines, pumps, lifts, etc. This excess power is therefore a direct gain, and enables us to consider the blast furnace, apart from its principal purpose, as an important source of motive power.

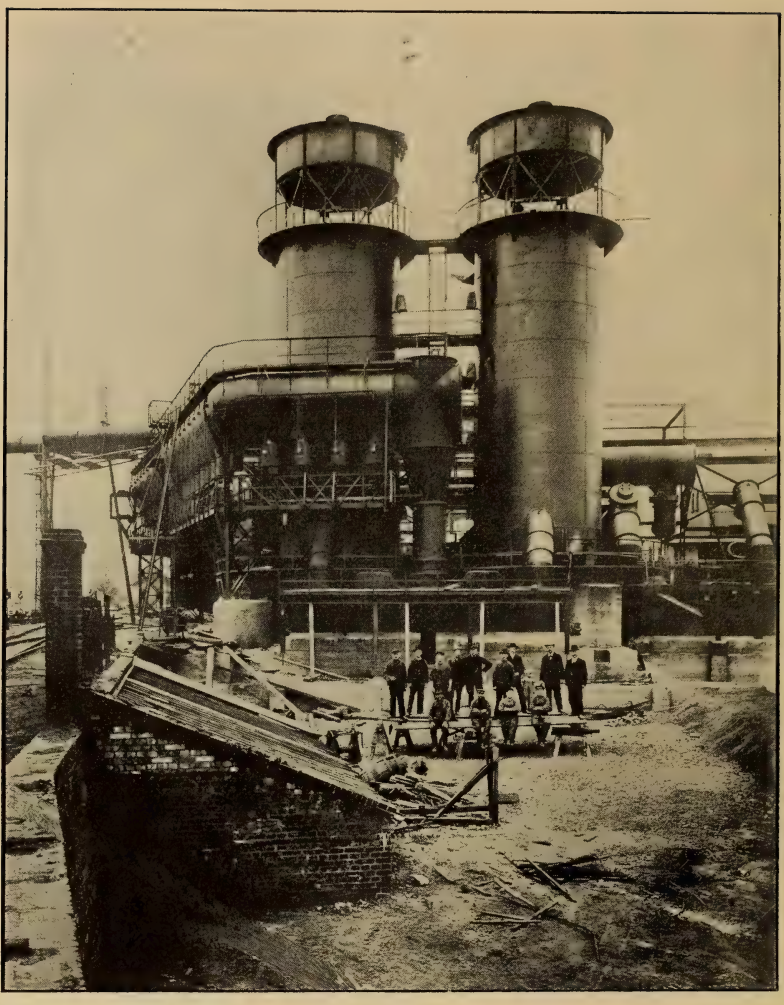
If we compare the efficiency of a ton of coal burned under a steam boiler, transforming scarcely 10 per cent. of its calorific energy into work in the steam engine, with the efficiency of a ton of coal transformed into coke and then utilized in the blast furnace, and if we take into account the value of the by-products and the motive power yet available, we must admit that it is possible to use the combustible in a very efficient manner in the metallurgical industry. This will become apparent by an inspection of the diagram.

The source of energy of which we intend especially to speak has become important only since the discovery that the waste gases of the coke oven and the blast furnace, the so-called "metallurgical gases," may be used directly in the gas engine; a discovery which dates only from the year 1894. Before that date there had been obtained only a very low efficiency by the burning of the gas under boilers to supply the steam engines of the establishment. These engines developed only about enough power to meet the demands of the furnace, and left no excess of power for disposal. This important discovery was followed by the practical construction of large gas engines, of sufficient power to solve the problem of the direct utilization of the great volumes of gas produced by these metallurgical gas producers. Only a few years were required to reach this point, and to-day we have gas engines of 3,000 to 4,000 horse-power; while continued experience with the development of 1,200 horse-power from a single cylinder enables us to state that no serious difficulty exists in the construction of engines of 5,000 to 6,000 horse-power. The development already made in this industry may be realized when it is stated that at the present time there is more than half-a-million horse-power actually produced from the waste gases of coke ovens and blast furnaces.

Among the various operative difficulties which are always to be expected in the introduction of a new industry, and from which the construction of the large gas engine has not been exempt, there is one which impeded their development. The dust contained in the gas from the blast furnace, and the sulphur existing in coke-oven gas, caused a fouling of the engines, producing rapid wear, and interfering with the regularity of their operation. This involved a thor-



THE JOHN COCKERILL WORKS AT SERAING, NEAR LIEGE, BELGIUM



ZSCHOCKKE APPARATUS FOR PRELIMINARY COOLING AND PURIFICATION OF GAS; CAPACITY 45,000 CUBIC METRES PER HOUR

The gas enters at 150 degrees C. and 5 grammes of dust per cubic metre, and is discharged at atmospheric temperature and a reduction of 60 per cent. of dust

ough cleansing of the gas, an operation in which some difficulties appeared. To-day, however, there are a number of devices in which the gases may be satisfactorily cleaned, and in fact a perfect cleaning may almost be said to be effected.

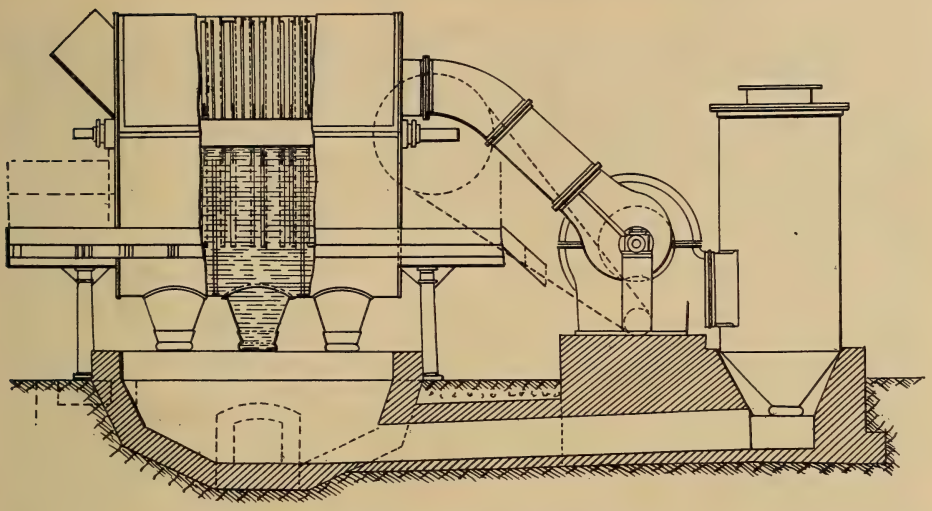
This cleaning of the gas has been recognized as advantageous also for the gas burned in the hot-blast stoves, and in modern blast-furnace equipment there is generally included some cleaning apparatus of large capacity such as the Zschokke or Bian, which receives all the gas, followed by a second device, such as a fan with water injection, or a washer of the Theisen type, for the final cleansing of that portion of the gas which is to be used in the engines.

Coke-oven gas, after passage through purifiers containing oxide of iron, contains only traces of sulphur.

II

What amount of power may be developed from these waste gases?

The results of recent trials upon



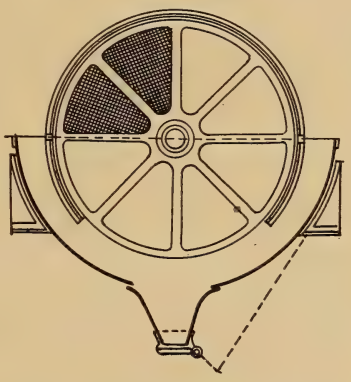
THEISEN GAS WASHER. LONGITUDINAL SECTION

a large double-acting, four-cycle, tandem gas engine, have shown a consumption of 2,355 calories per effective horse-power. If we allow about 5 per cent. for the power required to operate the apparatus for purifying the gas, we have a consumption of about 2,500 calories per effective horse-power.

As opposed to this, we have for steam engines or steam turbines, operated with good boilers, superheaters, re-heaters, and all the modern refinements, a consumption of not less than 6,000 calories per effective horse-power.

The conclusion follows that: Given a certain quantity of gas, its direct utilization in the internal-combustion motor permits the development of two-and-a-half times the amount of power which can be obtained from steam turbines or reciprocating engines of the most economical kind, if the gas is burned under steam boilers.

The modern by-product regenerative coke oven, considered as a gas producer, develops about 240 cubic metres of gas, of 4,000 calories thermal value, per metric ton of dry coal, containing 20 per cent. of volatile matter and 5 per cent. of ash. This gas is relatively rich, because of the presence of more than 50 per cent. of hydrogen. But a coke oven of this type requires the burning of the greater portion of the produced gas in the flues of the oven, there being about 35 per cent. left available for power, representing 336,000 calories.



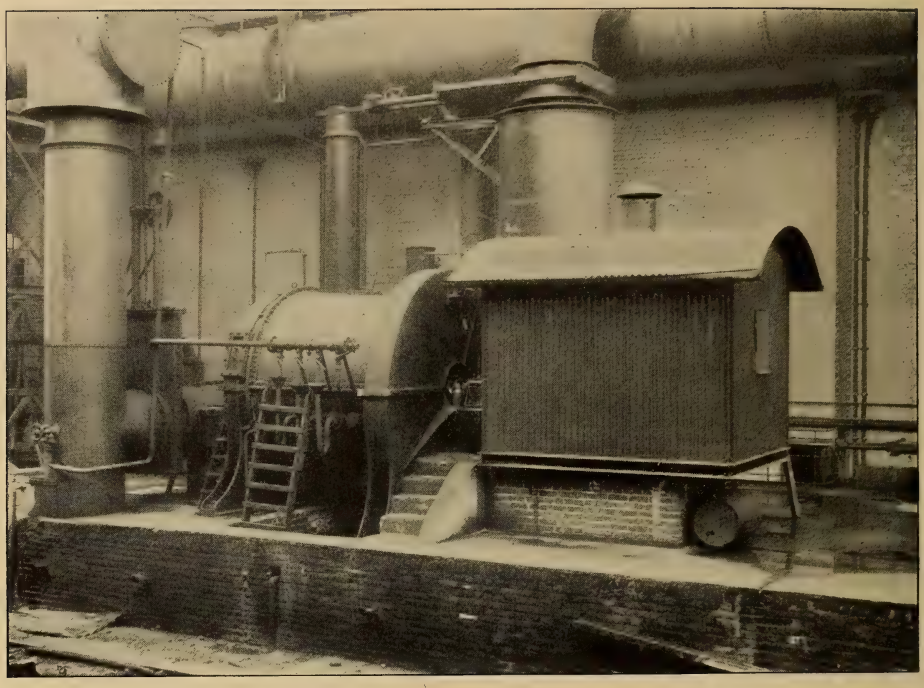
CROSS SECTION OF THEISEN WASHER

The gas produced by the distillation of a ton of coal gives, therefore, an excess of gas which permits of the development of:

$$\frac{336{,}000}{2{,}500} = 135$$

effective horse-power per hour.

As the time required for charging and discharging such a furnace is about 24 hours, it follows that the



THEISEN APPARATUS FOR SECOND PURIFICATION OF THE GAS, REDUCING THE DUST FROM 1 GRAMME PER CUBIC METRE TO 0.05 TO 0.02 GRAMME. CAPACITY, 4,000 HORSE-POWER

nominal power which may be derived from a coke oven is:

$$\frac{135}{24} = 5.6$$

for a furnace of one ton capacity. The production per ton of coal being 75 to 80 per cent. in coke, it follows that the production of power is about 7 horse-power per ton of coke per day. This result gives the ready rule that the power produced per hour is equal to the number of tons of coke produced per week.

Coming now to the blast furnace, there is produced 4,472 cubic metres of gas, of 950 calories thermal value per metric ton of coke consumed; this coke containing 15 per cent. of moisture and ash, and 85 per cent. of carbon. Of this total production of gas, representing 4,248,400 calories, 45 per cent. is absorbed by the hot-blast stoves and by various minor losses, while 15 per cent. is required for the motive power of the furnace, including the blowing engines, hoists, pumps, etc., leaving 40 per cent., or 1,699,360 calories, which is capable of developing energy equal to 680 horse-power per hour.

If we take the consumption of one ton of coke per ton of iron, we have for a furnace of one ton capacity per day available power equal to $\frac{680}{24} =$ nearly 30 horse-power per ton of iron produced. This corresponds to stating that the power produced per hour is about the same as the number of tons of iron made per month.

We may now draw up a sort of balance sheet, exhibiting the various operations and product of the coke oven and blast furnace:

One ton (metric) of coal containing:

Ash = 5 per cent., volatile matter = 20 per cent., carbon = 75 per cent., produces:

200 kilogrammes volatile matter.	$NH^3 = 2.5$ kilogrammes = 9.7 kilogrammes sulphate of ammonia.	
	Tar = 25 kilogrammes.	
	Benzol = 4.5 kilogrammes.	
	Motive power from the coke oven = 135 hp.	
750 kilogrammes carbon.	Plus iron ore = 800 kilogrammes pig iron. = 1,000 to 1,500 kilogrammes slag, producing cement and slag bricks.	
	Motive power from blast furnace gas.....	= 600 hp.
	Total power available.....	= 735 hp.

We thus see that after the coal has been deprived of valuable chemical constituents in the by-product oven, and after having played an important part in the operation of the blast furnace it yet contains a calorific power representing a very important amount of useful energy. This power is 60 per cent. greater than that which would be produced by burning the same amount of coal under a boiler, assuming all the steam produced to be used in a steam engine. These two discoveries, then, which came to light at the close of the last century, the regenerative, by-product coke oven, and the direct utilization of the waste gases of the coke oven and the blast furnace, have permitted metallurgical works to push the utilization of the combustible to a high degree of efficiency. Future generations will therefore not have to reproach the metallurgists with reckless waste of one of the natural sources of the wealth of industrial nations.

III

Since the metallurgical gases, considered as a necessary by-product of the operation of coke ovens and blast furnaces, require no additional expense for their production, there is no cost charge to be made for their generation, and this fact enables them to be used for the development of motive power for the works where they are produced to great advantage.

If it is proposed to install a central electric power station, using large gas engines as prime movers, to be operated in connection with an iron works, and using the waste gases from either coke ovens or blast fur-

JOHN COCKERILL COMPANY. BY-PRODUCT COKE OVENS PRODUCING 300 TONS OF COKE PER DAY

JOHN COCKERILL WORKS, SERAING. BY-PRODUCT COKE OVENS, CAPACITY 160 TONS PER DAY, WITH GAS POWER STATION

naces, or both, as fuel, either separately or mixed, the net cost of the power will depend upon:

1. The sinking fund charges, interest, depreciation, etc.
2. The operating expenses.
3. The co-efficient of utilization.

I. The sinking-fund charges include:

a. The cost of the plant, as installed.

b. The operative life of the plant.

c. The interest upon the capital tied up.

These expenses may be estimated, from experience in Belgium, at 400 francs per kilowatt installed, divided up as follows:

Gas engines	45	per cent.
Dynamos	15	"
Buildings	15	"
Foundations	5	"
Gas mains and purifying apparatus	15	"
Pumping machinery and water mains	5	"

If we provide a very liberal depreciation, assuming the entire plant to become obsolete in ten years, the annual value sunk corresponds to 13 per cent. of the capital involved, and this bearing interest at 5 per cent. amounts to 52 francs.

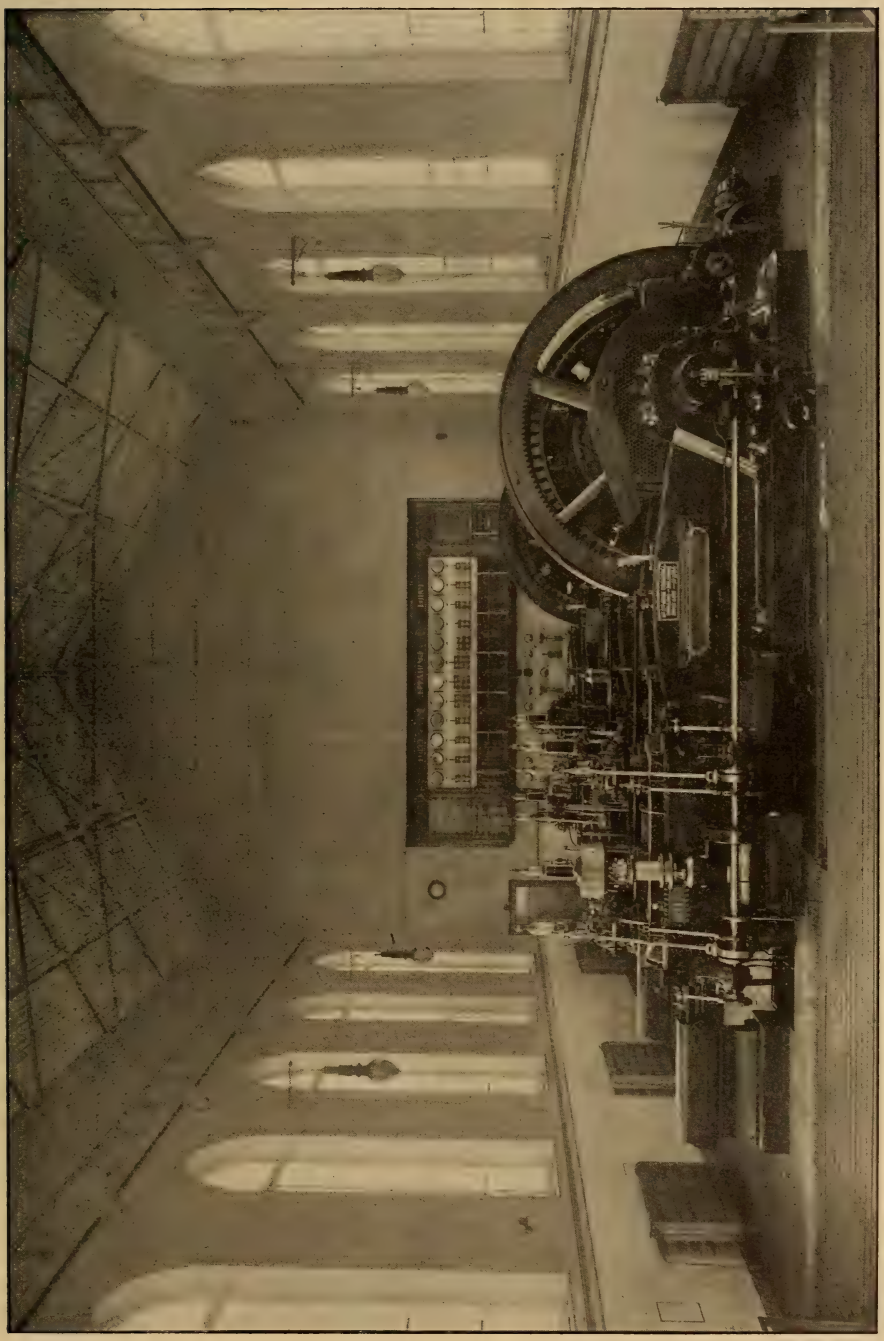
II. The operating expenses include:

a. Wages.

b. Lubrication.

c. Current maintenance and repairs.

It is difficult to estimate these several elements precisely; they vary in different localities. Actual results, however, are of interest, especially when they extend over a period of years of regular operation, and hence we give here data obtained in a Belgium establishment, the John Cockerill Works, at Seraing, in which there has been obtained a long experience in the construction and operation of large gas engines. This establishment possesses two electric stations, supplying current to about 600 electric motors of all sizes. One of these stations is supplied with blast-furnace gas, and has a capacity of 5,000 kilowatts; the other utilizes coke-oven gas, and develops 800 kilo-



JOHN COCKERILL COMPANY. STATION UTILIZING COKE OVEN GAS
The two engines develop 500 horse-power each. The gas available could develop 3,000 horse-power

watts. The Cockerill Company thus uses about 8,000 electrical horse-power derived from the waste gases of its blast furnaces and coke ovens.

During the past twelve months the production of electricity has increased to 24,000,000 kilowatt-hours, and the cost of operation divided by this number gives 0.65 centime as the net cost per kilowatt-hour.

This net cost includes:

	Wages	45 per cent
	Lubrication	20 "
	Maintenance and repairs	35 "

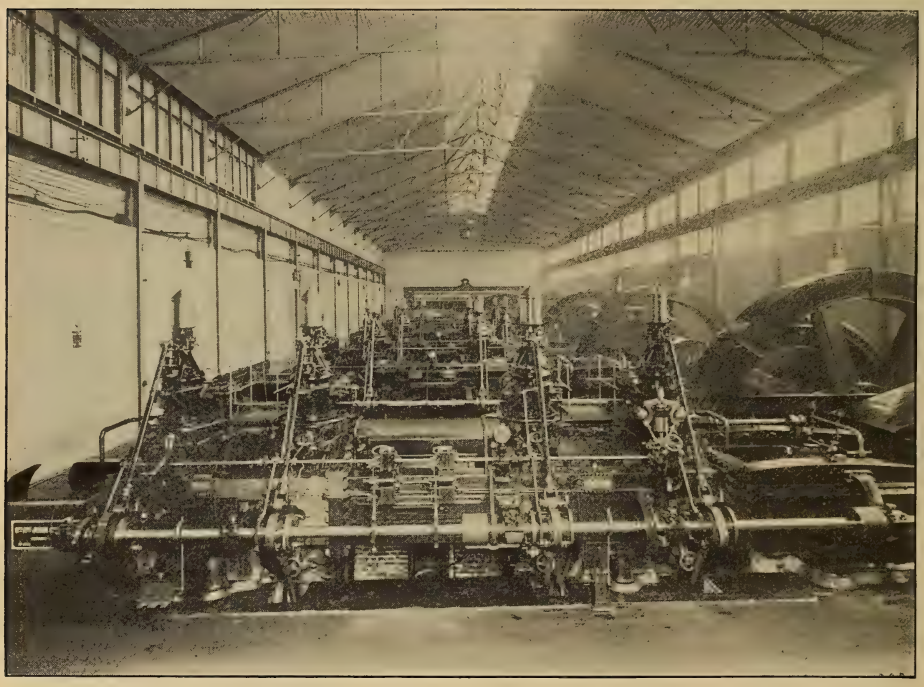
The Co-efficient of Utilization was 50 per cent.; that is to say, the number of hours of operation under full load, for all the units, was 4,800 hours. The complete net cost per kilowatt-hour may then be found as:

$$\frac{5{,}200}{4{,}800} + 0.65 = 1.83 \text{ centime.}$$

The following table gives the net cost which is obtained with higher co-efficients of utilization:

Coefficient.	Operation.	Sinking Fund.	Total.
50 per cent.	0.65	1.18	1.83
75 per cent.	0.43	0.79	1.22
100 per cent.	0.32	0.59	0.91

The cost thus works out to about 80 francs per kilowatt-year. It is common, however, to take this cost as equal to unity in making comparisons of the cost of electric power, this corresponding to a co-efficient of utilization of 100 per cent., this being a theoretical value, since we cannot admit that all the motors are operated under full load through the whole year without stop, and without reserve. The co-efficient of utilization does not depend upon the producer of the electric current, but upon the user, and it varies according to the nature of the industry. Average values may be taken as follows:



CENTRAL ELECTRICAL STATION AT THE COCKERILL WORKS. SIX ENGINES, TOTAL CAPACITY 7,000 ELECTRICAL HORSE-POWER

For industries which are operated day and night, without weekly stop, such as blast furnaces	90 per cent
For industries which are operated day and night, with weekly stop, such as steel mills	70 "
For industries which are operated during the day only, such as ordinary factories	35 "

The influence which the utilization of the waste gases of blast furnaces and coke ovens may have upon the rate of increase of production, and upon the net cost of electrical energy, is shown in the following table, based upon the operation of the power stations of the Cockerill Company during the past seven years. The first year shows the stations operated solely by steam power. By the close of the following year the installation of gas engines began, increasing each year, the steam engines being passed to the reserve, until, in 1906, they were entirely superseded.

Year.	Production, Kw-hours.	Net Cost for Operation, Centimes.
1900–1901, steam only.....	1,789,781	8.80
1901–1902, gas and steam....	1,930,740	7.76
1902–1903, gas and steam....	2,007,290	5.99
1903–1904, gas and steam....	5,387,612	2.96
1904–1905, gas and steam....	9,999 216	2.06
1905–1906, gas and steam....	14,915,919	1.63
1906–1907, gas only.....	24,000,000	0 65

IV

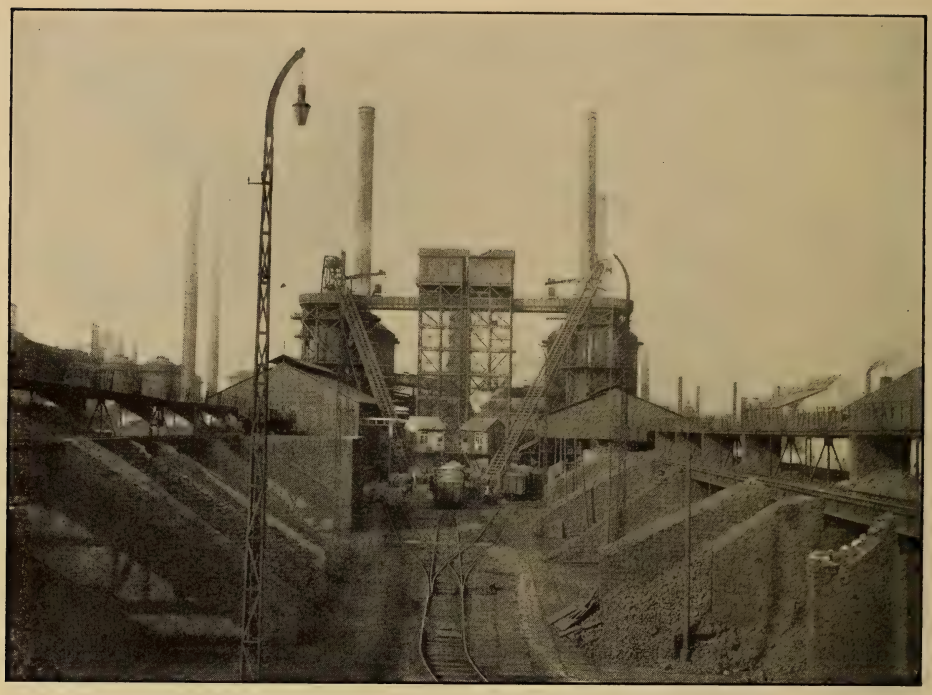
We have shown that coke ovens and blast furnaces constitute sources of motive power which modern methods enable to be made of great importance. Nevertheless the gas which they produce, like the power of a waterfall, cannot be accumulated or held in reserve by any practical method, and its energy must be employed immediately. This is readily done when the steel works and rolling mills are operated in the vicinity of the furnaces.

In such establishments the waste gases of the furnaces furnish sufficient power to provide for the entire operation of the mills. If the coke ovens are also in the neighborhood their gases may be used to increase the amount of power available, or better, they may be used to fire the various heating furnaces.

Under such conditions, a works receiving as raw material nothing but coal and ore, uses as combustible in the conversion of the latter into the finished steel product only the amount of coal necessary to make the coke used in the blast furnaces.

The generation of motive power is then limited to a central electric station, containing large gas engines supplying current to all the independent electric motors which operate the various machines in the works. If it is desired, however, the electric motors may be used for certain operations only, while the rolling mills and blowing engines may be driven directly by gas engines. This latter arrangement has been adopted in Germany in a number of works, and it has been found entirely practicable to drive continuous rolling mills as well as blowing engines directly by gas engines. For reversing trains, however, this system has not yet been applied, and it hardly seems practicable, at least for large powers. Still this arrangement has the advantage of avoiding the double transformation of power, but it lacks the important advantage of the central electric control of all the machinery, one of the strong points of the central electric station. The method which appears to promise the highest economy and efficiency in the utilization of gas power in a metallurgical establishment is the establishment of a main central electric power station, utilizing the gas from the blast furnaces, and another station for the use of the gas from the coke ovens; or better still, if possible, to unite them into one station, if the location of the furnaces and ovens will permit, and mix the gases for delivery to one set of engines.

This arrangement permits the development of a large amount of power, readily transmitted and delivered, at an extremely low cost. This is the very need of establishments which are seeking to reduce their operative charges and increase their output by replacing manual labor by machinery at every possible point. To effect this result it is essential that the electric motor should replace the steam engine at every point where it is now used in metallurgical operations, and that steam engine and boiler alike should disappear altogether. This is entirely



TWO OF THE SIX BLAST FURNACES AT THE COCKERILL WORKS

Total production of the six furnaces	800 tons per day
Gas production equivalent to	24,000 horse-power
Gas actually utilized	7,000 horse-power

possible. For a number of years the advantages of electric power in avoiding the use of long mechanical transmissions have caused it to be employed for operating travelling cranes, pumps, fans, saw-mill machinery, etc. It is only within a few years, however, that the use of the electric motor has been extended to the driving of heavy rolling mill machinery.

This department of industry has been rapidly developed, and the two principal constructors of Germany have installed up to the present time 200 electric motors, of which the combined normal power is 110,000 horse-power, and the maximum capacity is 200,000 horse-power. Among these motors are several capable of developing from 3,000 to 4,000 horse-power.

The slow movement of the reciprocating piston blowing engine renders it necessary to use some speed-reduction, such as belting or gearing, with the electric motor, and this is hardly desirable. The recent progress which has been made, however, in the construction of rotary pressure blowers renders it probable that electric driving of such machines will become not only possible, but even necessary, owing to the high rotative speed which they demand.

The only apparatus for which the steam engine has maintained absolute supremacy, the reversing rolling mill, seems now about to accept the electric motor. The problem of continual reversing with such powerful motors has been solved in an ingenious and effective manner. One of these rolling mills has now been in operation for several months, at the Hildegartenhütte, at Trzynietz, in Hungary. This motor absorbs an effort of 10,000 horse-power at a certain moment, but the power derived from the central station does not exceed 2,000

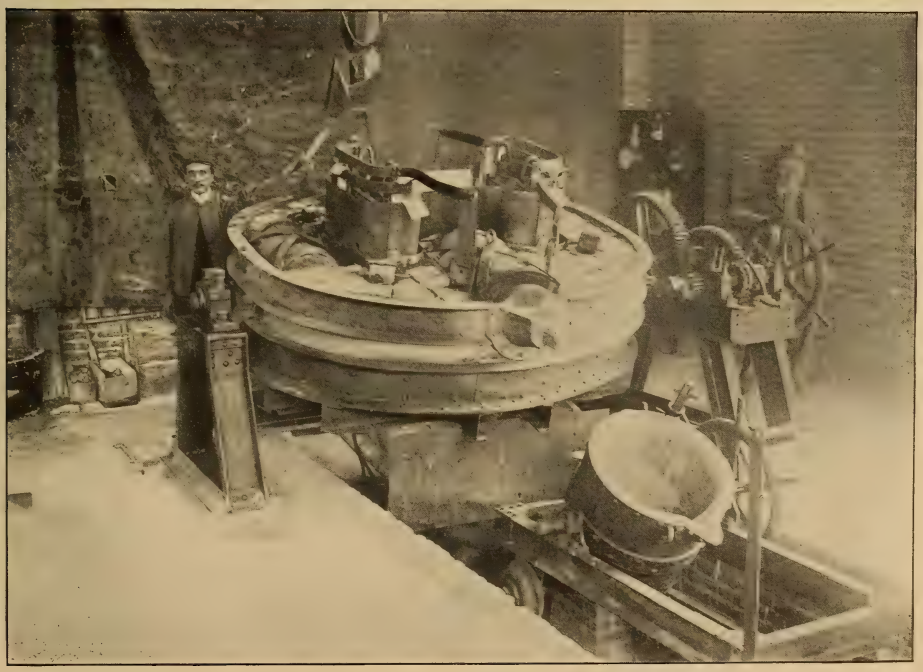
horse-power, the load being met by the action of heavy fly-wheels, arranged on the Ilgner system.

Five sets of similar reversing rolling mills are now under construction, and one ordered by the Rombach Ironworks is designed to be capable of absorbing 13,000 horse-power.

We may thus conclude that in all metallurgical works in which electric power can be cheaply procured by the direct utilization of blast furnace and coke oven gases, the steam engine is destined to disappear.

But establishments manufacturing coke and iron are not all in locations where they can utilize all the power at their disposal, and there are numerous isolated works which are able, by burning their waste gases under boilers, to produce all the power they need for their own purposes. It would seem that in such cases there is no reason for the installation of new and costly gas power plants for the production of an excess of power. What could they do with such additional power? There are numerous outlets for such power in neighboring industries, and for the adjoining municipalities. Lighting, tramways, the distribution of cheap power to small industries, offer opportunities for its use. If such works, thus becoming central power stations, do not desire to enter into the business of electric supply directly, they might well form an association for the distribution and sale of their excess power, even to its transmission over long distances.

Another plan appears for those metallurgical industries which prefer to retain their independence in utilizing the power available in the waste gases of their furnaces, and such may consider the creation of some new industry by the side of their coke ovens and blast furnaces. Such industries may be found in the operations of electro-chemistry and electro-metallurgy, both of which demand a large supply of electric current at low cost. This is precisely what has



INDUCTION STEEL FURNACE AT THE DOMMELDANGE WORKS, LUXEMBOURG. CAPACITY 500 KILOGRAMMES OF STEEL IN 8 HOURS, ABSORBING 1,100 KILOWATT-HOURS

occurred in the development of the power of waterfalls, where works for the production of chemical products and their metallic alloys have grown up. Similar industries may well be developed by the side of great iron works, since the price of 80 francs per horse-power per year is not greatly different from that of many hydro-electric stations.

Among such applications we may mention the manufacture of nitrates by the fixation of atmospheric nitrogen, and the production of oxygen by electrolysis, or still better, by the fractional distillation of liquid air, as of special importance to agriculture and general industry. The second of these should be of especial interest to the metallurgist, who, at the present time blows into his blast furnaces and converters a volume corresponding to four times the necessary amount of oxygen.

But the application of electricity which is of the most importance, and which appears to be most immediately applicable is the electro-metallurgy of steel. This question has made great progress recently, and has shown itself to be eminently adapted for the production of special steels for weapons and for tools, in which remarkable properties are produced by the action of high temperatures. It is probable that this process will become economical for the production even of ordinary steels, in large quantities.

One of the most interesting applications already in use, employing directly the utilization of blast-furnace gas, is that at the Forges d'Eich, in the Grand Duchy of Luxembourg. This works operates several blast furnaces, and has installed a number of gas engines, placing at its disposition an important quantity of motive power, enabling it to undertake the direct production of steel in the electric furnace. One furnace of a capacity of 500 kilogrammes has been in operation for several months, and we give some data concerning the cost of steel thus produced:

	Kilogrammes.	Francs.
Cast iron	400	24.00
Scrap	100	9.35
Mill scale	120 kilogrammes	3.00
CaO	120 "	1.80
Ferro Mn	7 "	2.85
	500	41.00
Electric current, 1,115 kw-hours at 0.005		= 5.55
Labor		8.00
		54.55
Charge	500 kilogrammes	
5 per cent loss	25	
	475	
Ferro Mn	7	
	482 kilogrammes steel.	

From which the cost of the steel is

$$\frac{54.55}{482} = 0.12 \text{ Fr.} = 120 \text{ Fr. per ton.}$$

The duration of the operation is eight hours, and the power required for this furnace is 150 kilowatts, or 200 electrical horse-power. This, however, is an experiment on a small scale. It is certain, therefore, that a more powerful furnace should have a higher efficiency, and that the cost of 120 francs per ton may be considered as a maximum; even if the cost per kilowatt hour is taken at 1 centime, instead of $\frac{1}{2}$ centime.

Larger electric furnaces are in operation in other establishments, but these, in general, operate only with steel scrap, introduced in the liquid state from the open-hearth furnace into the electric furnace, the electric operation consisting only of a refining action, purifying the steel almost completely, and thus improving its quality.

From what has preceded, the present importance of the production of motive power at a low price will be perceived, and it will be seen that the utilization of the waste gases of blast furnaces and coke ovens in gas engines has opened the way to one of the most important movements which has yet occurred in the economic history of the metallurgical industries.

THE UTILIZATION OF LOW-GRADE FUELS IN THE GAS PRODUCER

By C. T. Wilkinson

One of the especial advantages of gas power appears in the opportunity which it offers for the satisfactory and efficient utilization of fuels of such a low grade that they cannot be successfully consumed under the steam boiler. This claim has been made for the gas producer at various times, but it remained to be demonstrated beyond doubt or question by the important experimental researches conducted by the United States Geological Survey, beginning at the St. Louis Exposition, and continued since.

These exhaustive tests are covering a great variety of fuels, and the reports already issued contain much valuable information. Mr. Wilkinson has examined these results with the especial object of showing the extent to which low-grade fuels may be employed in the generation of power gas, and he gives accurate data of tests upon four such fuels, in comparison with a high-grade steam coal. The results are convincing, and should lead to the extensive installation of producers and gas engines in the districts where such fuels are readily available.—The Editor.

FUNDAMENTAL in the consideration of all power schemes is a thorough knowledge of the values of all fuels available, not only with respect to the British thermal units per pound, but also to the features determining their practicable value in boiler or gas-producer work.

The investigations of the fuel-testing plant of the United States Geological Survey have recently led to some remarkable results in the utilization of low-grade fuels, such as soft coals, lignites, bone coals, and even peats for gas-producer work. Further, it has been found that coals with a high percentage of impurities, such as sulphur and ash, can be used successfully, making excellent fuel for the producer. Coals containing up to 7.36 per cent. of sulphur were used and coals with as high as 23.44 per cent. of ash, both giving excellent results. In fact, there is indication that coals containing up to 50 per cent. of ash or even more could be used, provided it did not form clinkers and was not so fine as to pack in the producer.

Another point of considerable interest is the discovery that very fine coals can be used provided the fragments are prismatic and not dust or plates, and that this refuse will give practically as good results as lump coal, while we must remember for use under the steam boiler the size of the coal is of great importance and slack and weathered coal gives poor results.

The present status of the investigations along these lines may possibly be best indicated by the following examples of a Dakota low-grade coal, a Texas lignite, a Florida peat, a bone coal, and a Virginia steaming coal. Before, however, examining these results it is advisable to refer to the apparatus in which they were made. The gas-producer plants consisted of two 250 H. P. Taylor pressure gas-producers with inside diameter of brick lining or jacket 7 feet, area of fuel bed 38.5 square feet, height of top casing 15 feet. This plant supplies a 235 horse-power Westinghouse gas engine belted to a direct-current electric generator.

The steaming plant consisted of a Heine boiler and an Allis-Chalmers Corliss engine, rated 200 horse-power, non-condensing, with a fuel consumption of about 24 pounds of steam per horse-power-hour at full load. All this apparatus is the same as that installed at the St. Louis section of the Geological Survey fuel-testing plant, and further details may be found by reference to any of the publications of that department.*

*Bul. 290 and Professional Paper 48, U. S. Geol. Survey

A DAKOTA LOW-GRADE FUEL

This fuel is typical of a large number of so-called low-grade fuels, and is illustrated by the following proximate analysis:

NORTH DAKOTA NO. 3

North Dakota, No. 3.	Analysis of Coal Used in Boiler Test. Per Cent.	Analysis of Coal Used in Producer Test. Per Cent.
Moisture	35.96	35.78
Volatile matter	31.92	28.76
Fixed carbon	24.37	29.01
Ash	7.75	6.45
	100.00	100.00
Average B. T. U. coal, per pound		7.069
Average B. T. U. gas, per cubic foot		158.9
Cubic feet of gas produced per pound of coal as fired		26.1
Cubic feet of gas per pound of dry coal		40.7

The producer-gas test on this fuel gave coal, as fired per electrical horse-power at switchboard, 3.1 pounds, while a steaming test under the Heine boiler gave coal, as fired per electrical horse-power, 8.46 pounds.

Hence from these remarkably poor coals good results can be obtained in the producer, while it is evident that they are of little value for steam boiler work.

TEXAS LIGNITE

The following sample of Texas lignite containing:

	Analysis of Coal Used in Producer Test. Per Cent.
Moisture	33.71
Volatile matter	29.25
Fixed carbon	29.76
Ash	7.28
Sulphur	0.53
Average B. T. U. coal, per pound	7,348
Standard gas 62° F. pressure	14.7
Standard gas per pound of coal as fired, cubic feet	34.2
Standard gas per pound of dry coal, cubic feet	51.6
B. T. U. standard gas per cubic foot	156.2

This fuel gave a remarkably good efficiency in a producer plant when its quality is considered, namely, coal, as fired per electrical horse-power-hour, 2.47 pounds. It will be noted that this coal actually contained only about 60 per cent. real fuel.

FLORIDA PEAT

The sample consisted of a machine peat made by the Leavitt process and sun-dried. In this process the peat first passes through the condenser, which disintegrates the material and destroys the fibre. From the condenser the peat is passed to a moulding machine and thence loaded on wagons and hauled to the drying ground, where the bricks are allowed to lose from 60 to 75 per cent. of their moisture content. The peat bricks, as fired, give the following proximate analysis:

	Analysis of Fuel Used in Boiler Test. Per Cent.	Analysis of Fuel Used in Producer Test. Per Cent.
Moisture	17.21	21.00
Volatile matter	51.01	51.72
Fixed carbon	24.85	22.11
Ash	6.93	5.17
	100.00	100.00
Average B. T. U. of peat, per pound		10,882
Average B. T. U. gas, per cubic foot		175.2
Cubic feet of gas produced per pound of coal as fired		30.3
Cubic feet of gas produced per pound of dry coal		38.3

The steaming test showed 4.27 pounds of water were evaporated per pound of peat fired, and a value of "peat as fired per electrical horse-power" of 6.98 pounds. The gas-producer test, however, showed a "value of peat as fired per electrical horse-power developed at switchboard" of 2.85 pounds.

BONE COAL

The fuel used for this test was so-called "bone coal," heretofore untried in the producer and one which is considered of practically no value for steam-boiler work. The coal was received at the producer in 8 and 10-inch lumps, some of which appeared to be a high grade of bituminous coal, while some appeared to be ordinary rocks and would give off sparks when hit with a hammer. Despite this appearance of rocks the fuel had no tendency to clinker or coke and worked well in the producer, requiring scarcely any poking. The coal contained a large amount of ash, which caused the ash to increase in thickness very rapidly, and as a consequence a mistake was made in not grinding down often enough. The result of the thick ash bed was to condense the steam, thus causing a reduction in the calorific power of the

gas produced. Such modest claims were made for this coal that no attempt was made to carry full load at first; but as the results warranted, the load was increased until eventually full load was carried for thirty-nine hours, at the end of which time the accumulation of ash in the producer caused a little trouble, necessitating a reduction of the load until considerable grinding down could be done, when full load was resumed. This coal had an analysis as follows:

	Analysis of Coal Used in Producer Test. Per Cent.
Moisture	0.47
Volatile matter	8.83
Fixed carbon	46.96
Ash	43.74
	100.00
Average B. T. U. coal, per pound	8,566
Average B. T. U. of standard gas, per cubic foot	144.0
Cubic feet of gas produced per pound of coal as fired	44.1
Cubic feet of gas produced per pound of dry coal	44.3

VIRGINIA STEAMING COAL.

As an example of what a recognized steaming coal will do in a gas producer the following test is selected. This coal had a proximate analysis of car sample as follows:

	Analysis of Coal Used in Boiler Test. Per Cent.	Analysis of Coal Used in Producer Test. Per Cent.
Moisture	3.74	2.65
Volatile matter	31.04	31.00
Fixed carbon	61.31	62.82
Ash	3.91	3.53
	100.00	100 00
Average B. T. U. coal, per pound		14,436
Average B. T. U., per cubic foot		139.2
Cubic feet of gas produced per pound of coal as fired		100.8
Cubic feet of gas per pound of dry coal		103.5

The steaming test showed a consumption of 3.45 pounds of coal as fired per electrical horse-power-hour, and the producer gas test a consumption of 1.04 pounds of coal as fired per electrical horse-power-hour developed at switchboard. It is thus evident that coals of this nature may give results in the producer—at least three times better than if they are burned under the steam boiler.

The above results give material for very careful thought by all power users and power producers. They seem to indicate the opening of a wide field for the application of gas-producer work, and the simultaneous development of a class of fuels otherwise worthless, the mining of which at present is not considered a commercial possibility.

In considering these remarkable results developed by the fuel-testing section of the United States Geological Survey, due consideration should be given to the type or class of apparatus employed in the tests, and they should be taken rather as circumstantial evidence pointing to vast possibilities, but at the same time possibilities which we as a nation of engineers have no right to disregard.

THE GAS-POWER SITUATION IN GERMANY

A DISCUSSION OF RECENT PROGRESS IN THE DESIGN AND CONSTRUCTION OF LARGE GAS ENGINES

By F. E. Junge

HE who has carefully studied German industrial developments in the field of gas power generation and conversion must arrive at a résumé of the situation in the different departments somewhat as follows:—

IRON AND STEEL INDUSTRIES

The vast and continuously increasing demand for iron and steel in every line must be accompanied, invariably, (1) by the growing difficulty to find suitable ores in sufficient quantities and qualities, and in convenient proximity to the fuel supply; (2) by an increase in the weight of coke that must be charged at the furnaces together with the ores for smelting the latter; (3) by a rise in the cost of production, owing to the higher prices that must be paid for ore, fuels and labour.

Therefore the productive efficiency of iron and steel works, especially of those independent works that do not control the transportation factor, and their capability to compete with other producers will in future depend, more than ever before, on the right husbanding and proper valuation of the raw materials, fuels and by-products of the plant. Great savings in operating cost can be realized through the judicious utilization of waste gases and inferior fuels and their application to a variety of purposes within the works, for which at present costly steam coal must be bought. On the other hand, the earning capacity of iron and steel works can be greatly increased by adding to the remunerative returns from the finished goods those yielded by waste and low grade coals when sold as heat or light or power to outside consumers in the neighbouring districts.

COAL MINING AND COKE MAKING

Since iron and steel works, in order to be able to work with maximum industrial economy, have mostly coal mines and coke-oven plants controlled by the works, the above reasoning can with certain limitations be extended also to these departments. Conditions are somewhat different in that the power factor, or the ratio of fuel consumed for plant operation to fuel available, is rather an insignificant amount, unless excessive depth of shafts or high-water influx offer exceptional resistances to the flow of the product. Where coke-oven gases and inferior grades of coal, such as mine culm, dust coal, etc., are available, gas power remains the only profitable and sometimes the only possible means or mode of generation for a judicious administration to adopt, as, for instance, when combined with electric centralization. It must be remembered that coke-oven gas as emanating from modern by-product ovens, besides being superior in calorific value to blast-furnace gas, needs not be specially cleaned for use in gas engines as must be the latter. Further, that coke dust, unless briquetted, is hardly fit for raising steam under boilers, or for heating furnaces, while mine culm is not applicable at all. Here the gas producer comes in as the only service-

able apparatus for utilizing this low-grade material which otherwise would be utterly wasted.

ELECTRIC CENTRAL STATIONS

We need not dwell again on the now undisputed thermal superiority of gas prime movers over other modes of power generation for this class of work, irrespective whether the fuel used is gaseous, solid or liquid. Neither do we have to evince that their mechanical features have now been developed to a condition of reliability and standardization equal to any of their various competitors. It is universally conceded that the success of our claimant lies, apart from its adaptation to a few special services such as blowing, rolling, pumping and the propulsion of vessels, with the concentration of large power units in the central station, where all the weaknesses of the engine can, by proper attendance, be most effectively counteracted, and its good points, by proper load distribution, fully secured. The use of gas from some cheap source of generation for driving large gas-electric generators offers the only method at the present time of securing such high and continuous economies as are essential to enable one to employ electric current for the operation of railways for purposes of lighting, for long-distance distribution of energy, for the centralization of industrial establishments, efficiently on a large scale.

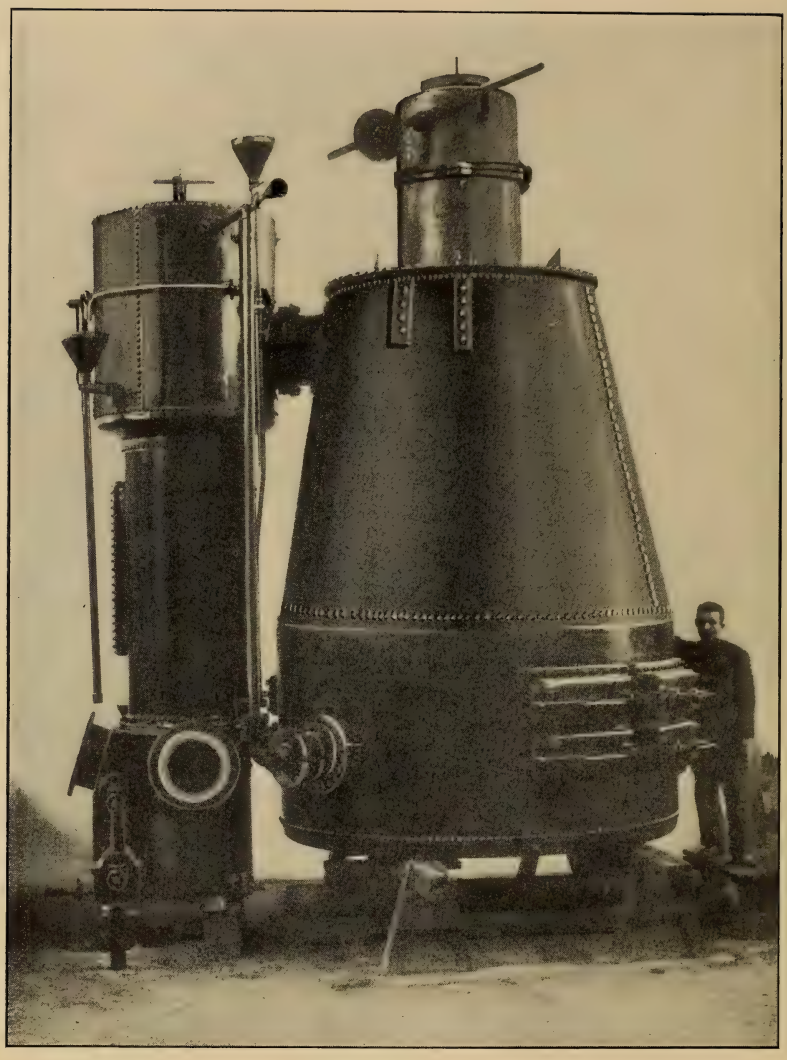
GAS PRODUCER PLANTS

In the gasification of coal in producers there was, until recently, altogether too much importance attached to the employment of such high-grade fuels as anthracite and coke. Gas producers burning this class of coals represent merely a transient phase in the ultimate development, and are applicable and capable of competition with existing steam and hydro-electric power plants in the smaller sizes only. Advocating, as we do, nothing less than the complete abandonment under certain conditions of the traditional and wasteful, but universally adopted and reliable method of power generation by steam in favour of a new system, it is essential that the economies which we guarantee be sufficiently high to appeal to the American investor. Thus we must add to the high efficiency of conversion of the kinetic coal energy into work, the greater economy of using inferior and cheap grades of coal, together with such as have hitherto escaped utilization entirely. We have now succeeded in developing apparatus which can use successfully such low-grade fuels as lignite, peat, dust coal, mine culm, etc., at the same time recovering whenever possible the valuable by-products from coal tar, which were hitherto wasted. Thus gas power has arrived at a phase of evolution in which it is enabled to cope with water and steam in their most privileged spheres.

After this general survey of the economic aspects of our subject I will proceed to enumerate briefly the tendencies which characterize the standard construction of large gas engines, "made in Germany," whence they have spread, partly by licensed transplantation, partly by illegitimate imitation, all over the world.

FRAME

The crank case is formed between the two main bearing supports and serves as a receptacle for the lubricant. A circular guide bed for the cross-head, and a flange to which is bolted the front end of the first cylinder of the (tandem) combination completes the equipment. Accessibility to the cross-head is secured in some types by cutting down the upper edges of the side walls, while strength and fairly central distribution of forces are attained by connecting the cylinder flange and the main bearings by heavy tie-rods at a considerable distance above the horizontal center plane. The main pressure transmitted through the connecting rod being directed toward the

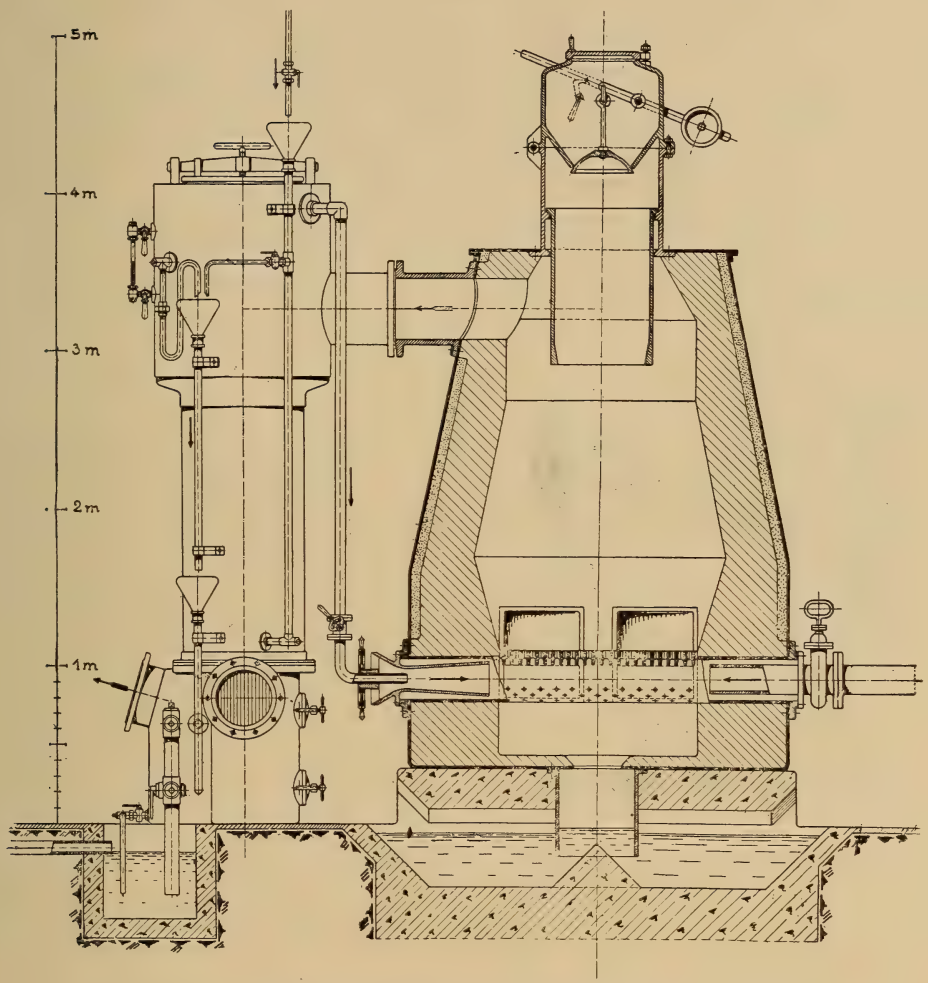


EXTERIOR VIEW OF NURNBERG GAS PRODUCER FOR COKE BREEZE. CAPACITY 500 TO 600 HORSE-POWER

guide below, there are only two ledges provided in this design to keep the cross-head in a true path.

In other types, and almost universally in the larger sizes where the side walls of the frame are so high that it is impossible to get access to the moving parts from above, the top is closed by a solid wall cast with the frame, serving to transmit all forces applied in front at the main bearings to the circular back flange. Accessibility is here secured by providing two good-sized openings in the side walls of the frame. Thus the whole casting can be machined by the boring-bar at one setting and requires no other treatment. The circular guide-bed and the face of the flange must therefore be absolutely true.

The heavy frame rests on the foundation along its entire length, being held down to the block by long anchor bolts, while the distance-piece and tail end of the (tandem)



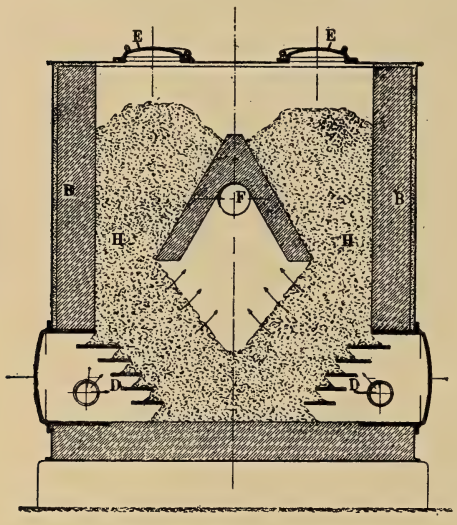
SECTIONAL VIEW OF NURNBERG PRODUCER FOR USE WITH COKE BREEZE. CAPACITY 500 TO 600 HORSE-POWER

combination and their accessories are supported by base plates. They are fastened thereto so as to allow free expansion longitudinally or parallel to the center line of the engine; the variations in length being due to the influx and efflux of heat. Altogether the actual expansion is very slight, since efficiently controlled cooling of cylinders, pistons, and rods keeps down the average internal temperatures below that of modern steam engines working with superheated steam.

This is a remarkable performance, considering the difficulties under which gas engines compared to steam engines have to work. With steam engines a temperature of the superheated steam of 350 degrees C. seems to be the economic maximum, while in gas engines temperatures as high as 2,000 degrees C. are recorded. In view of the fact that a temperature of 500 degrees C. represents the limit of resistance of all materials that can be employed for building these engines, it will be evident that efficient cooling is a requisite of principal importance for this class of work. In a comparison at hand, the difference in longitudinal

expansion and contraction, owing to the extremes of heat flow of a steam engine 65.6 feet long was 0.6 inches, and of the piston rod 0.7 inches. The corresponding figures of a gas engine of equal length are 0.08 and 0.1 inch respectively.

When large gas engines are built, not merely for sale, but for service, it is a dangerous practice to reduce the initial price and the cost of erection of frames by cutting out one of the



PINTSCH PRODUCER FOR COAL DUST. AIR AND STEAM ENTER AT D, D, GAS DISCHARGED AT F

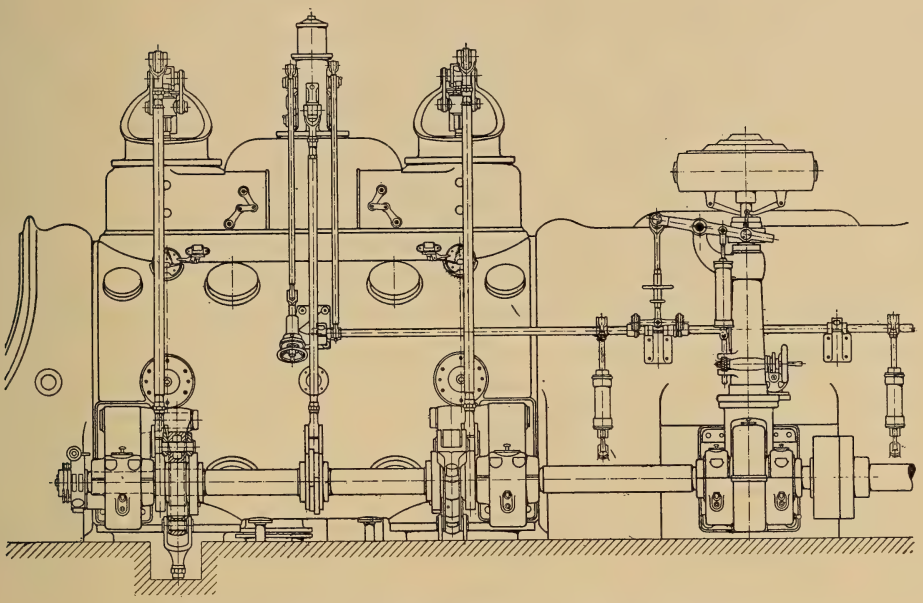
two main bearings, since this must weaken the stability of the entire system considerably. The bill which the power user must pay for repairs and interruptions in service caused by the frequent break-downs of the Corliss beam-type of frame is far greater than the amount of investment in a second bearing, which latter construction has proven its merits in many years of actual practice and under the severest conditions of continuous operation on the European Continent.

CYLINDER

In addition to what I have said elsewhere* on the subject it may be mentioned here that of the principal modes of design:—(1) Cylinder and jacket cast in one; (2) jacket split peripherally at one or more places to facilitate expansion and contraction of the system; (3) separate liner fitted into the breech end of jacket casting, permitting the choice of specially suitable material and allowing to exchange and rebore the cylinder proper. The first is the one most often used. A novelty has been introduced in that the outer cylinder walls are made thicker so as to fit them better for transmitting the heavy stresses, while the inner walls are kept thinner in order to increase the cooling influence of the jacket water. Another feature adopted by some builders consists in giving the end flanges which connect the cylinder with the main frame or tail end and distance piece, respectively, a tapering form. Cone-shaped flanges with a minimum of flange section seem to be superior in transmitting great forces from outer to inner walls directly without springing. Simplicity, symmetrical form, wide water spaces, ample diameter of curved edges are the principal requirements to impart elasticity to the system. Therefore, ribs, especially longitudinal ones and others which are apt to make the walls inflexible, must not be employed.

There is also a tendency noticeable to discard the valve pockets, which were adopted originally with a view to reduce thereby the total length of cylinders, also to prevent valve disks when torn from the stems by the constant hammering on the seats, from falling into the cylinder and working destruction. None of these suppositions proved sound. The reduction of total cylinder length is inconsiderable, and valve disks are not torn from their stems. But the points in the immediate vicinity of pockets and lugs connecting the inner barrel with the outer walls are most liable to fracture. And the residual burnt gases which assemble in the dead spaces are liable during

* Design, construction, and application of large gas engines in Europe, "Power," 1905, 1906, 1907.

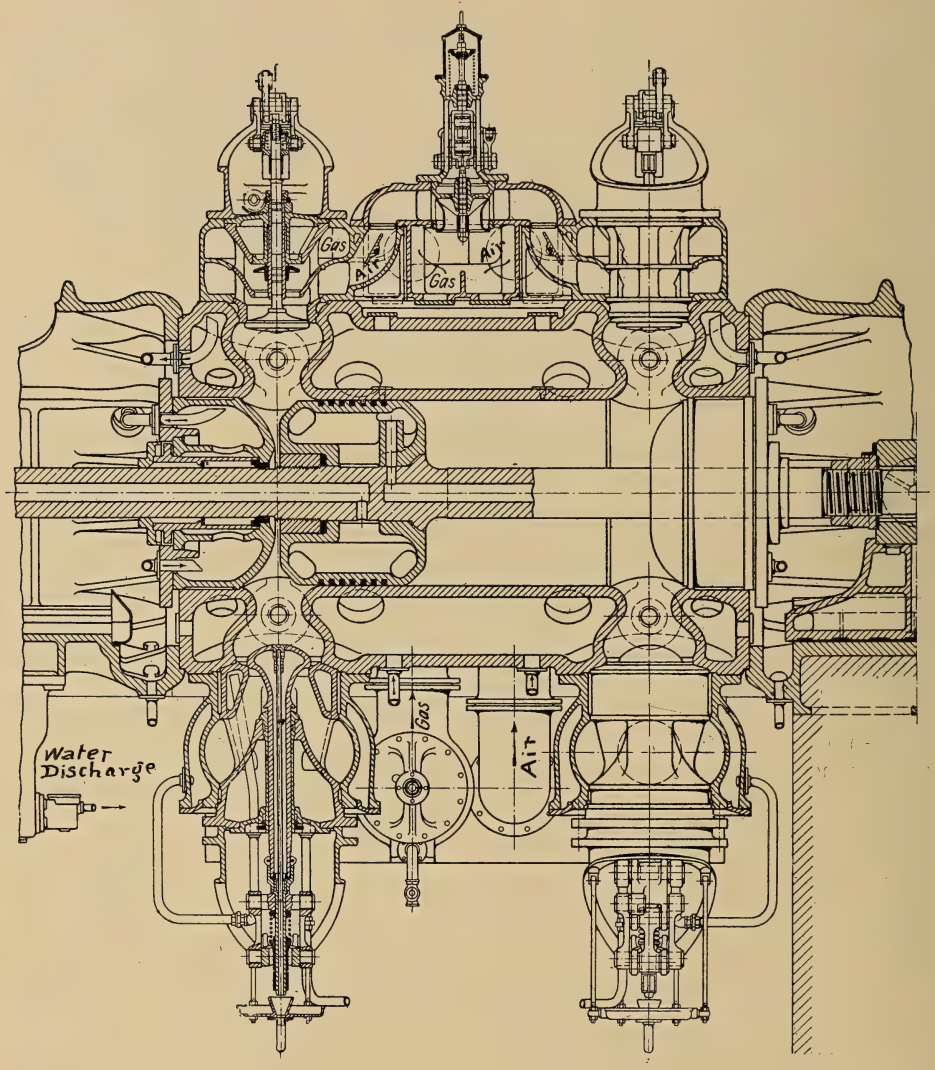


FRONT CYLINDER OF DEUTZ TANDEM 2,000 HORSE-POWER ENGINE

compression to cause premature explosion of the fresh charge, owing to their excessive temperatures. Better scavenging is secured by giving the combustion chamber a clean cylindrical or annular form, by properly timing the opening of the exhaust valve, and by installing the exhaust pipes in such manner that the inertia of the column of burnt gases helps to withdraw from the cylinder its residual contents.

Parts of the cylinder that appear weak can be suitably strengthened by means of tie-rods or compression bolts. These bolts were employed originally in repairing cylinders that had cracked. Now they form an intrinsic portion of the construction. The idea is to produce initial pressure stresses in longitudinal as well as in axial direction which counteract the tension forces that occur when the cylinder gets heated up, thus producing by the mutual counteraction of the two forces a state of rest or equilibrium. Of course, the heat efflux from the system is reduced by these bolts, and it remains to be seen which effect is the less harmful. Contraction rings are similar contrivances. They may be placed around the weaker parts of the cylinder, being either forged or rolled with a larger diameter.

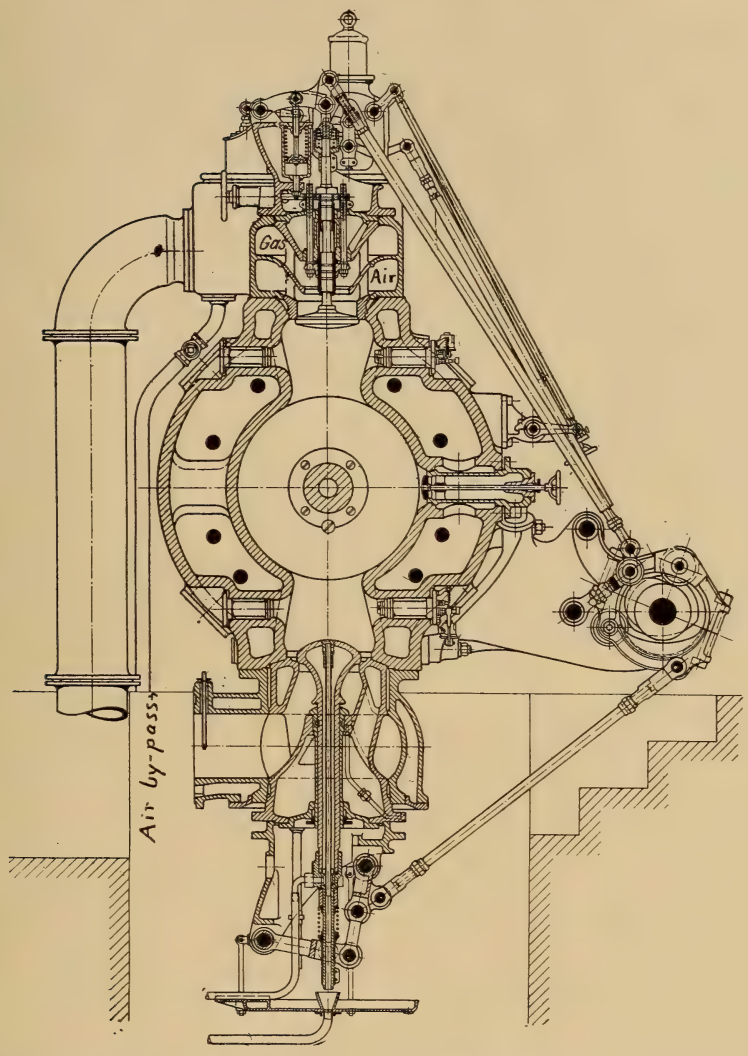
The abandoning of valve pockets, or, in any case, their less rigid connection with the outer walls is one of the main reasons that few instances of cracked cylinders have been heard of during the last years. In exceptional cases where they did occur, those who have investigated the matter are agreed that the cause of the breakage had nothing to do with the construction, but was to be attributed to the pressure of water in the cylinder, to the formation of blow holes, and to the settling of dirt in corners and edges of the water space. In most cases fractures are due to insufficient cooling, caused by the use of uncleaned cooling water, separating out its dirt at the resistances which obstruct the path of flow. Altogether, as has been said, internal temperatures in modern large gas engines are kept within moderate limits, cooled as the cylinders are externally by the jacket and internally by covers, piston and rods, notwithstanding the high temperature of combustion.



FRONT CYLINDER, PISTON, VALVES AND ACCESSORIES OF DEUTZ 2,000 HORSE-POWER GAS ENGINE

PISTON

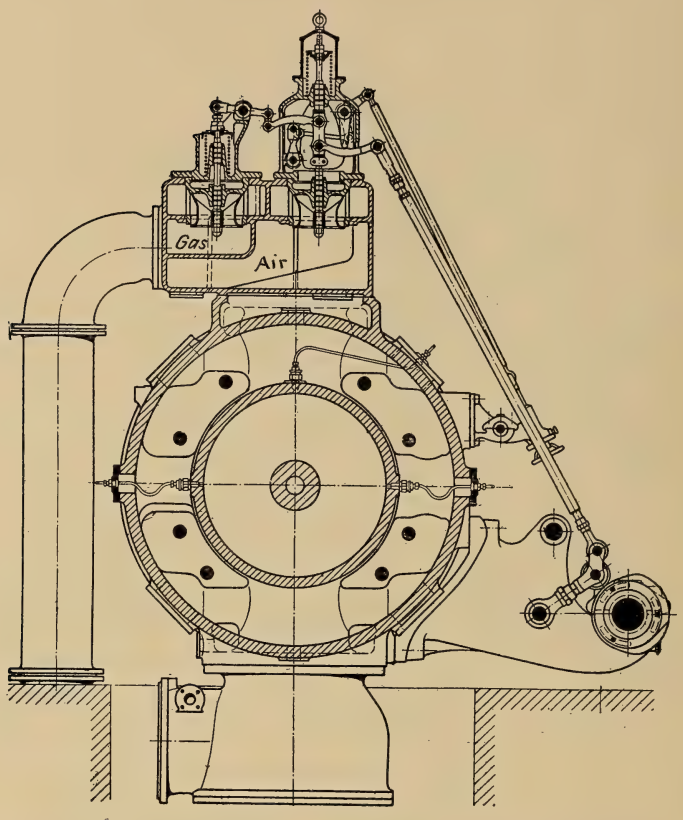
Experience has shown that it is not advisable to stiffen pistons with ribs, especially not with transverse ones, since these, as is the case with cylinders and covers, are often the cause of fracture. It has been rather difficult to find an all-round suitable form of design. According to Reinhardt, pistons broke both when they were made in one, or in several pieces, and when they were low or high in tensile strength. With the thickness of walls necessary to transmit the energy of the explosion, the initial stresses in pistons are already dangerous, wherefore it is necessary to anneal the cast-steel pistons after casting. With pistons divided into two parts, great attention must be given to the water-tight joint to prevent leakage of the cooling water, the pressure of which is between 44 and 74 pounds at the circumference of the piston, as even the smallest leakage prevents the formation of



SECTION THROUGH INLET AND EXHAUST VALVES AND STARTING VALVE AND GEAR. DEUTZ 2,000 HORSE-POWER ENGINE

the electric spark necessary for ignition.

Finally, the fixing of the piston on the rod is a very important point. The old method of securing the piston to the piston rod by a screwed end and a nut may be employed if the materials of the rod and nut are of very different hardness; otherwise, as proved by experience, a slackening of the nut is often impossible. The Cockerill Works, Belgium, employ a construction in which the two halves of the piston are pressed against a flange forged on the piston rod by small screws which can easily be slackened. An even better design is that adopted by the firm of Schüchtermann & Kremer, Dortmund, in which the screws that serve to connect the two halves of the piston are located quite outside the reach of the cooling water and require no packing at all. After they have been tightened from without, the opening that contains the nuts is closed by a ring composed of two parts, which are fastened by a few



SECTION THROUGH AIR AND GAS VALVES AND GOVERNING GEAR OF DEUTZ 2,000 HORSE-POWER ENGINE

small screws to the body of the piston, whereupon the piston rings are secured in place.

The cooling of the piston is now generally so arranged that the cooling water enters the rod at one end and flows out at the other. Backflowing is avoided by a pipe which is fitted in the bore of the piston rod. In tandem engines this arrangement is either on each cylinder, or the cooling water is allowed to pass through both rods and both pistons, one after the other. In the first case, the cooling water must enter at a pressure of from $2\frac{1}{2}$ to 3 atmospheres, and in the second from $4\frac{1}{2}$ to 5 atmospheres.

The firm of G. Luther, of Braunschweig, in their double-acting engines, arranges for the inlet and outlet of the cooling water at one and the same end of the piston rod. This, owing to the necessity of having an inner return pipe, is regarded as a less durable construction. But by avoiding the employment of stuffing boxes it is simpler than the ordinary design. The inertia forces which occur at the end of each stroke when a certain number of revolutions is attained, will rend and expel the inner column of water in the inner dead center. At the next reversal of the stroke in the outer dead center, the outer column of water, being longer than the inner one, will enter the inner return pipe at the front end of the rod, while the check valve in the back supporting head opens automatically. Thus the whole process of internal cooling becomes simple and automatic.

As in the construction of cylinders, the continuous changes of the compression and tension forces

which are exercised internally by the combined actions of the influx of heat and the weight of oscillating water may be compensated by the employment of longitudinal connecting bolts producing external pressure stresses. The provision of ribs for strengthening plates, and especially the placing of these on the surface side which is subjected to tension forces is a grave mistake, which will invariably lead to fracture.

CRANK AND BEARINGS

Owing to the high internal pressures occuring in the working process of large gas engines, the dimensions and weights of crankshafts become much larger than those common in steam-engine practice. At the same time the difficulties of steel works in turning out these monstrous parts are greatly increased. Crank-shafts are forged from solid steel blocks, the weight of which runs up to 65 tons and more per piece, while the weight of the finished crank is about half that much.

The proportioning of the bearing surfaces and their lubrication, according to the duty and service which an engine is to perform, requires the most careful consideration of the designer. Of no less importance is the proper balancing of the heavy reciprocating masses of the tandem engine, which continues to be the standard type for four-cycle work. The crank-shaft should be adjustable in two directions and should run in white-metal bearings equipped with ring lubrication of the positive feed and regulable temperature type. Two rings, one on each end of the bearing, are preferable to one. They allow a better control of the oil admission, at the same time avoiding a weakening of the bearing shells through perforations.

When driving large alternators special care must be taken in dimensioning and erecting the outer bearing, otherwise trouble will be experienced with overheating, owing to insufficient wearing surface. The outer bearing becomes thus very long, up to 3 feet and more, and provisions must be made to the effect that the supporting shells can adjust themselves in tangential direction to the elastic line. Hence they should have a ball-shaped support. The bending of the shaft by the weight of the generator wheel, which serves as fly-wheel at the same time, is compensated by mounting the outer bearing somewhat higher than the main frame. When combining engines in twin fashion the two outer bearings are raised by some tenths of a millimeter in order to secure perfect alignment.

VALVES AND GEAR

While the inlet valve has never given any serious trouble when properly designed, the exhaust valve is still the most vulnerable organism of large gas engines. Therefore all attempts of builders center in the desire to keep this part well cooled and to make it readily accessible and easy of removal. Not only is the exhaust valve and its cage arranged so that both can be inspected, cleaned and repaired without taking down any of the exhaust-pipe connections, but there are two important firms, Schüchtermann and Kremer, and Körting, who have gone so far as to abandon the standard form of four-cycle design,—inlet and exhaust valves placed diametrically opposite on top and bottom ends of cylinders,—and have arranged the exhaust valves sideways, so that they can be taken out quicker without being obstructed by the piston rod above. To reduce the stresses which are exercised by the gas pressure and gear respectively, on exhaust valve and cage during the period of opening (40 to 60 pounds per square inch), either a small relief valve is provided, which opens earlier than the main exhaust, or what is better and simpler, the exhaust valve is balanced. One firm employs exhaust

slots as an auxiliary means for reducing the end pressure of expansion and for expelling the main portion of the hot gases, a construction which is reliable and effective, but because of the considerable increase in total length of cylinder and engine cannot be commended. Tandem engines, especially in combination with blowing cylinders, are already very long, and the larger the floor space which they occupy, the less pronounced becomes the advantage which they possess over steam turbine-driven Parsons blowers.

Reference has already been made to the practice, with gas engine installations having a straight line of exhaust piping, of having the opening of the exhaust begin about 15 per cent. in advance, and prolong it somewhat beyond the finish of the stroke, during which time the admission has slightly commenced. At this juncture the burnt gases have attained a high velocity, which causes a powerful suction in the cylinder. The atmospheric air rushes into the explosion chamber, more or less completely sweeping out the burnt gaseous residuals which would hang in the vicinity of the sparking plug and tend to interfere with the ignition of the mixture. It should be remembered, however, that the useful effects of an arrangement of this kind are entirely dependent on local conditions of installation.

TWO VERSUS FOUR-CYCLE

A few words may be added on this question, which has now been sufficiently clarified to allow one to arrive at something like definite conclusions, so far as the present standard types of both systems are concerned. Double-acting two-cycle engines of the improved Körting type are superior to the tandem combination of four-cycle engines for certain services: blowing, compressing, pumping and direct-roll drive, on account of their superior capability of manœuvering, and of their greater reliability in operation. These advantages are due to the employment of separate pumps for scavenging and charging. Gas and air being pressed into the cylinder in regulable quantities according to the load, securing a perfect mixture owing to the high rate of diffusion of the gaseous molecules, the power cylinder is practically independent of pressure variations of the two constituents of the charge in their respective admission pipes. Hence, speed regulation, from the maximum to the lower limit,—which is naturally fixed by the weight of flywheel,—can be executed with absolute certainty.

Further, double-acting, two-cycle engines will start quicker even than steam engines, and with a heavy load on, needing only low air pressures in the receiver. Their total length also is considerably shorter than that of the tandem combinations, which is of importance when driving blowing engines. Their greater reliability in operation is due to the absence of exhaust valves, the discharge slots used, when cut in a separate cylinder liner, being an absolutely safe and enduring organism. Lubrication, which in modern practice is effected through the piston, can be made more perfect with long pistons than with short ones.

Against these advantages stands the drawback that the work expended in two-cycle engines for charging is a greater amount than the corresponding item in four-cycle work, amounting as it does in the latest two-cycle constructions to 6 or 7 per cent. of the total indicated output. Moreover,—and this is the reason which precludes the employment of double-acting, two-cycle engines for driving large alternators,—their speed cannot be increased beyond a certain maximum, which remains considerably below that of four-cycle tandem engines. Thus a double-acting, two-cycle engine of 1,000 H. P. cannot very well run faster than at 85 revolutions per minute, while a tandem combination

of the same size runs normally at from 107 to 110 revolutions. Hence there is with the last named type a saving in cost of generator and weight of fly-wheel.

Also, the accuracy of governing is greater since, in two-cycle engines the quantity of gas enclosed between pump and inlet valve escapes regulation, so that the governing effect is somewhat retarded. Finally there is this drawback about double-acting, two-cycle engines as built at present, that the capacity of single units is practically limited to 1,200 H. P. in one cylinder. Beyond this capacity the double-acting, four-cycle tandem engine will be given preference.

In conclusion, a few words may be said on the differing tendencies of gas-engine construction in the United States and in Germany. American builders are apparently working under the delusion that they will ultimately conquer their home market by reducing the cost price per unit output of these machines to the level of steam engines, thus offering for sale an attractive piece of mechanism, which, with the same initial capital outlay on the part of the investor, is purported to save him one-half and more in fuel expenditure. In Germany we have been realizing for some time that it is impossible to build an engine giving highest all-round efficiency at the same low price and for the same class of attendance as one of inferior qualities, and that by cutting out parts of its elaborate mechanism in order to make it "fool proof" we will, invariably, cut down its superior fuel economy and its fitness for certain services as well.

Neither can we afford to weaken the productive efficiency of our large industrial enterprises by constantly tearing down the old and rebuilding on a new scale, which is the continuing order in some departments of the American industry, contrasting strongly to the stagnation,—caused by extreme systematization and specialization,—which precludes the possibility of progress and improvement in others. One more difference exists in that, after a period of probation in practice, the efficiencies as well as the operative difficulties of these engines are ascertained by impartial investigators, and, what is even more important, the results good *and* bad are made public in the technical press for the benefit of industrial circles at large. I must leave it to the thoughtful student of American industrial conditions to decide whether or not it is wise for the gas power circles in this country to assimilate their methods of design, construction and application of large gas engines to those "made in Germany."

SHIP PROPULSION BY INTERNAL-COMBUSTION ENGINES

By A. Vennell Coster, M. Inst. Mech. E.

YEARS ago an able lecture was delivered by Sir William Anderson on the "Inter-dependence of Abstract Science and Engineering," and undoubtedly the many famous engineering firms now strenuously engaged in the development of marine gas propulsion recognize this—theory in connection with all maritime matters must go hand in hand with practice. Great and absorbing interest is being shown in the subject of this article, and while the interest deepens, so in like degree greater reticence is being shown by the pioneers now engaged in its development than hitherto. All the more difficult is it, therefore, for the author to state exactly the present position of affairs; but that events are moving on rapidly and that difficulties are being met and overcome are absolute certainties. The leading engineering societies of many countries have already appreciated these advances, and the patent records speak volumes as to the scientific evolution of embryonic theories into successful practice. The Parsons steam turbine required ten years of indefatigable toil to make it a commercial success, and to a large extent it has paved the way for the introduction of the marine internal-combustion engine; and the probabilities are that within the next ten years this will become one of the main prime movers in both mercantile marine and navy. As stated by the author in a previous lecture, from the point of view of thermal efficiency the gas engine is bound to win. The following diagram, prepared and brought up to date, and corroborated by the highest authorities on marine propulsion, states the case for the internal-combustion engine.

In diagram, Fig. 1, of marine gas engines, the figures are taken from actual gas engines and plants developing their power from bituminous coal. These are average figures, easily obtained in present practice.

In Figs. 2 and 3 the usual marine cylindrical boiler, with internal firegrate and return tubes, is considered. Authorities give the average heat efficiency of such marine steam boilers from 66.7 per cent. to 70 per cent. This is rarely exceeded at sea when one takes into consideration the losses due to cleaning fires, etc. The efficiency on the indicated horsepower for gas engines is taken as 33 per cent., Fig. 1 giving a practical thermal efficiency of about 30 per cent. for vertical Otto type gas engines. The thermal efficiency of the whole plant works out to 23.8 per cent. It is not so easy to arrive at the thermal efficiency of marine steam turbines nor of their mechanical efficiency. From actual experiments taken with two vessels (in duplicate, as far as form and weight surface are concerned, one driven by turbines, the other by twin screws, at the same speed, including all necessary auxiliary machinery, and working between the same temperature ranges) the thermal efficiency of the turbine, based on the indicated power, may be taken as 20 per cent., with a vacuum of 27 inches, the mechanical efficiency as 93 per cent.

In Fig. 3, for marine reciprocating steam engines, the efficiency on the indicated power is given as 17 per cent., the mechanical efficiency as 92 per cent. As a rough commercial

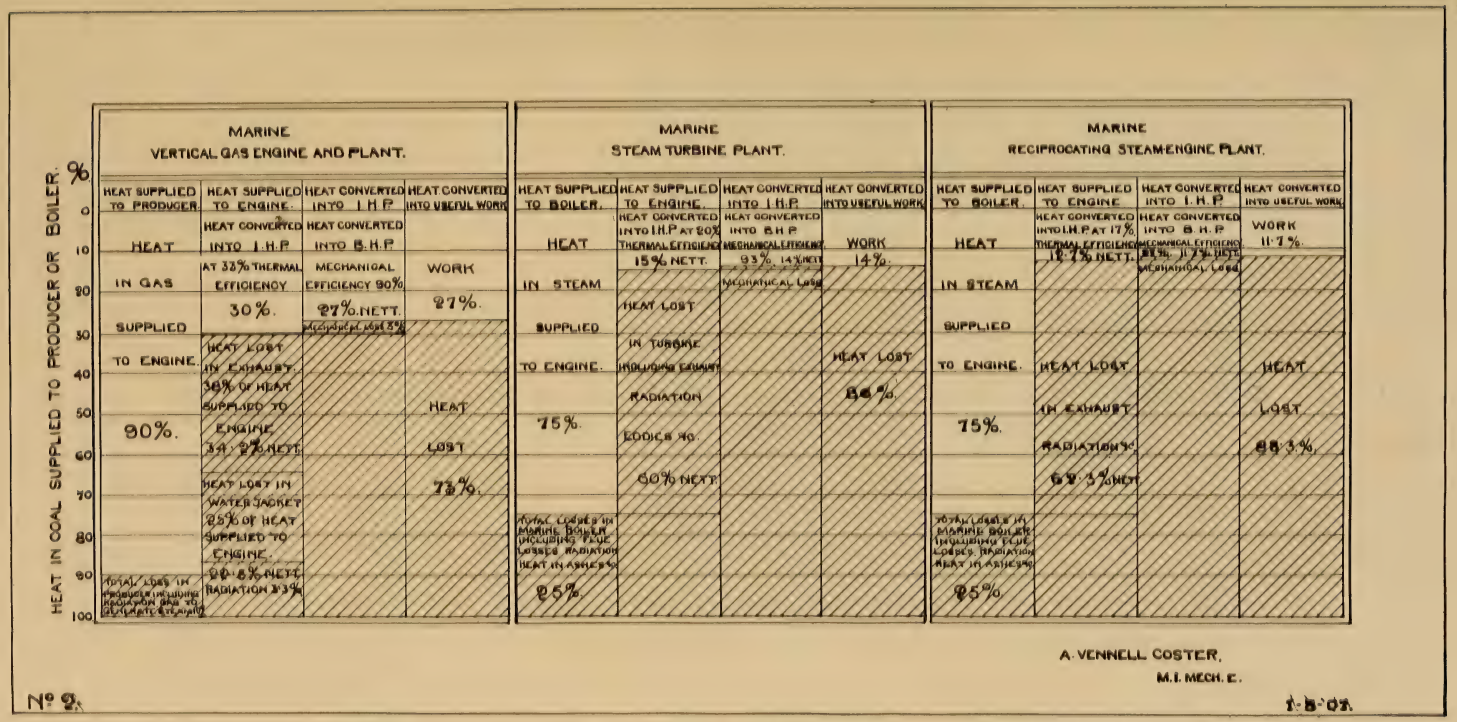

HEAT IN COAL SUPPLIED TO PRODUCER OR BOILER. %
0
10
20
30
40
50
60
70
80
90
100
MARINE
VERTICAL GAS ENGINE AND PLANT.
HEAT SUPPLIED TO PRODUCER.
HEAT IN GAS SUPPLIED TO ENGINE. 90%.
TOTAL LOSS IN PRODUCER INCLUDING RADIATION GAS TO SCRUBBER & WASTE
HEAT SUPPLIED TO ENGINE.
HEAT CONVERTED INTO I.H.P AT 32% THERMAL EFFICIENCY 30%.
HEAT LOST IN EXHAUST. 36% OF HEAT SUPPLIED TO ENGINE. 34.2% NETT.
HEAT LOST IN WATER JACKET 25% OF HEAT SUPPLIED TO ENGINE. 22.8% NETT.
RADIATION 2.3%
HEAT CONVERTED INTO I.H.P
HEAT CONVERTED INTO B.H.P MECHANICAL EFFICIENCY 90% 27% NETT.
MECHANICAL LOSS 3%
HEAT CONVERTED INTO USEFUL WORK
27%.
HEAT LOST 73%.
MARINE
STEAM TURBINE PLANT.
HEAT SUPPLIED TO BOILER.
HEAT IN STEAM SUPPLIED TO ENGINE. 75%.
TOTAL LOSSES IN MARINE BOILER INCLUDING FLUE LOSSES RADIATION HEAT IN ASHES 5% 25%
HEAT SUPPLIED TO ENGINE.
HEAT CONVERTED INTO I.H.P AT 20% THERMAL EFFICIENCY 15% NETT.
HEAT LOST IN TURBINE INCLUDING EXHAUST RADIATION LOSSES 10. 50% NETT
HEAT CONVERTED INTO I.H.P
HEAT CONVERTED INTO B.H.P MECHANICAL EFFICIENCY 93%. 14% NETT.
MECHANICAL LOSS
HEAT CONVERTED INTO USEFUL WORK
WORK 14%.
HEAT LOST 86%.
MARINE
RECIPROCATING STEAM-ENGINE PLANT.
HEAT SUPPLIED TO BOILER.
HEAT IN STEAM SUPPLIED TO ENGINE. 75%.
TOTAL LOSSES IN MARINE BOILER INCLUDING FLUE LOSSES, RADIATION HEAT IN ASHES 5% 25%
HEAT SUPPLIED TO ENGINE
HEAT CONVERTED INTO I.H.P AT 17% THERMAL EFFICIENCY 12.75% NETT.
HEAT LOST IN EXHAUST RADIATION &c 62.25% NETT
HEAT CONVERTED INTO I.H.P
HEAT CONVERTED INTO B.H.P MECHANICAL EFFICIENCY 85% 11.7% NETT.
MECHANICAL LOSS
HEAT CONVERTED INTO USEFUL WORK
WORK 11.7%.
HEAT LOST 88.3%.
A. VENNELL COSTER,
M.I. MECH. E.
No 2.
1-8-07.

FIG. 1.—MARINE GAS ENGINES

FIG. 2.—MARINE STEAM TURBINES

FIG. 3.—RECIPROCATING ENGINES

comparison on the basis of these figures we may safely assume that of the total heat in the coal the gas engine turns into actual work about twice as much as the best marine reciprocating engine or marine steam turbine. The fuel consumption with the steam plants is from 1.3 to 1.6 pounds per indicated horse-power, and with gas plants from 0.65 to 0.8 pounds per horse-power, so that either the vessel's radius of action may be increased 100 per cent. or the bunker space may be reduced 50 per cent. in favour of gas as compared with steam.

As seen on the heat balance sheet, Fig. 1, 38 per cent. of the total heat developed in the gas engine cylinder is wasted down the exhaust pipe. This heat can be utilized on shipboard for many purposes, but for no purpose better than for use in a distilling plant, usually supplied to all sea-going vessels, and by means of which all water, whether brought from the shore or not, may be purified. It may be safely assumed that after allowing for some loss due to radiation from the exhaust pipe connected to such a plant, there will be about 3,000 B. T. U. per horse-power per hour left for changing water at 60 deg. F. into steam at 212 deg. F., so that the waste heat in the exhaust of a 500 horse-power marine internal combustion engine can supply 80 gallons of distilled water per hour, allowing 60 per cent. efficiency for the distilling plant. This is a point worth considering by marine gas engineers; the distilling plant also acts as a silencer.

Among the many advantages claimed for gas propulsion are the following:—

1.—The vessel may be driven the same distance with half the amount of fuel, or radius of action increased 100 per cent.

2.—Stand-by losses reduced over 75 per cent.

3.—Reduced racing in a heavy seaway, due to smaller and more deeply immersed propellers.

4.—Having two or more propellers (on similar lines to steam turbine driven vessels); less liability to stoppage at sea, and greater handiness when entering port or in narrow waters, as the ship can be steered by the propellers when it has insufficient way on to be controlled by the rudder.

5.—Working pressure confined to the engine cylinders, the gas producers working under atmospheric pressure.

6.—Easy firing and stoking; the gas producers may be charged only twice every twenty-four hours, and the rolling and pitching of the vessel being rather an advantage than otherwise in assisting the fuel down from the charging hoppers.

7.—The gas producer makes its own steam at about atmospheric pressure; no steam pressure boilers are required with the following serious and constant disadvantages:—

(*a*) Priming of boilers and water hammer in steam pipes.

(*b*) Bursting of boiler tubes and steam pipes and joints, the collapse of furnace crowns.

(*c*) Corrosion and pitting of boilers from engine oil forming acids in the condenser and being deposited in the boiler by the return hot feed-water.

It is acknowledged that the weak place of every steam installation is the boiler; this in the gas plant is entirely eliminated.

8.—No condenser and maintenance of a good working vacuum necessary.

9.—Reduction of weight and space occupied by gas engines and producers as compared with steam engines and boilers.

10.—Less auxiliary running machinery required and fewer pipes and joints to keep tight.

11.—Cleaner ship, because no smoke and less handling of coal.

Regarding the other side of the question the chief difficulties are:—

1.—The construction of a simple gas producer of the suction type,

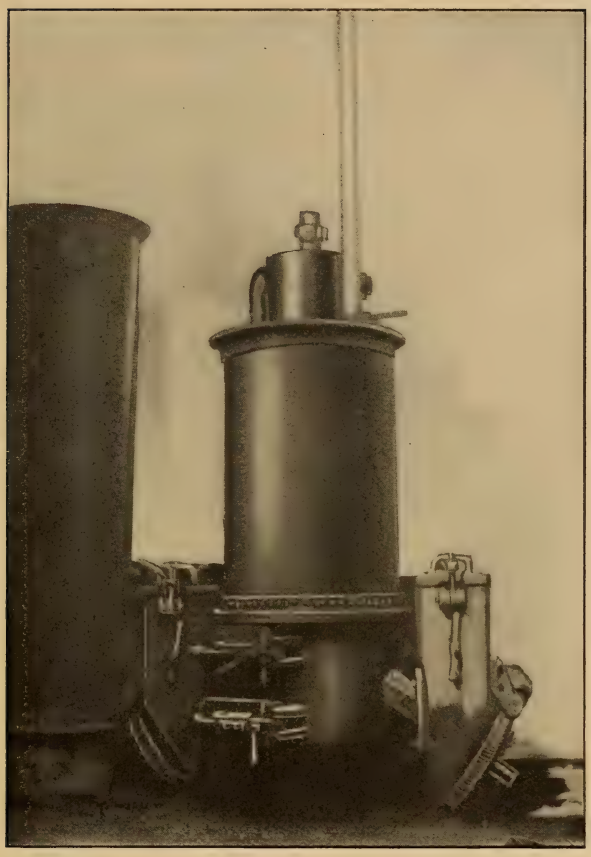


FIG. 4.—BREGEOT UNDER-FEED MARINE GAS PRODUCER

able to make good gas from bituminous fuel, having fluctuations of calorific value within certain limits; entirely free from tar or dust, and designed to generate gas continuously.

2.—The provision of a system of ventilation to prevent gas leakage into the vessel with consequent dangers of asphyxiation.

3.—The maintenance of perfect control of the gas-propelled vessel in starting, stopping, reversing and running at all speeds.

Regarding No. 1, which is the main difficulty of our programme, I can state that this has already been solved in a perfectly satisfactory manner to suit the rough-and-tumble conditions of service at sea, in a plant of about 100 horse power.

This, of course, is of very small dimensions when compared with the powers necessary for navigating ocean liners, but it is well to remember that it is far easier to govern the working conditions of a large gas plant than of a small one, and that having overcome the many difficulties inherent in this type of gas producer of this size, one need not fear the construction of larger plants having greater elasticity in their arrangements for successful working. One outstanding feature of all these suction producers for bituminous fuel is the necessity of having some positive mechanism for the breaking up of the fuel while in the coking process. One arrangement of such a plant designed by a French engineer may be seen in Fig.

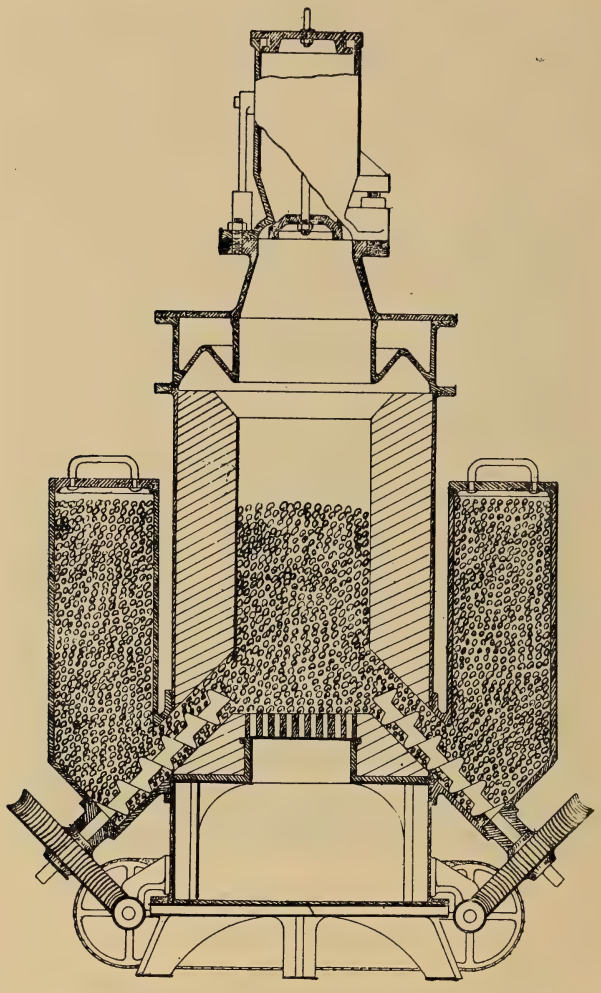


FIG. 5.—CROSS SECTION OF UNDER-FEED MARINE GAS PRODUCER

4. In this case the furnace is of the under-feed type, a system concerning which the author years ago considered satisfactory for marine purposes. It has spiral conveyors which force up fuel inch by inch into the furnace, tangentially with the furnace centre.

From accounts received, this system appears to be working successfully with some types of fuel. As may be seen, the fuel is pushed up by two Archimedean screws, and enters the producer at the bottom of the furnace. The continuous turning movement of the fuel makes the ashes and clinkers fall, and causes an easy passage for the air and vapour to the centre of the fire space. Under these circumstances, it is claimed that the tar and impurities of the semi-caking or caking coal, as soon as they become disengaged, mix with the air and vapour, which mount through the grids fixed at the bottom of the furnace and are immediately burned in their upward passage through the bed of incandescent coal, which acts as an impenetrable barrier; a filter of fire, which continually cleanses itself, destroys all impurities, and even transforms them into useful gas. As is

well known, with anthracite fuel the producer practically performs its own stoking, but not so with bituminous coal. As has already been said, additional mechanical means must be supplied to prevent the caking and clinkering of the fuel, whether delivered to the producer above or below.

On further consideration, it appears to the author that for marine purposes the suction bituminous gas producer must not only be simple, but must conform as much as possible to the laws of Nature; that is, that the fuel in the producer should fall in the process of combustion and that the gas should rise in its process of evolution. There have been many attempts, some of them partially successful, in which these laws have been (wholly or in part) defied. The coal has been pushed up against gravity into the furnace, and in some cases, as in the down-draught producers, the gas is made to pass down and through the zone of heat in the producer to its exit.

The author has been asked as to the utility of "Coalite" as a fuel for use in marine suction gas plants. There can be no doubt that when its price is sufficiently reduced below that of anthracite it will be in great demand for this purpose, being a non-caking, smokeless fuel and containing no tar. The following independent analysis confirms this:—

COALITE

	Per Cent.
Fixed carbon	81.00
Volatile matter	6.00
Sulphur	0.50
Moisture	3.80
Ash	8.70
Total	100.00

when compared with anthracite as follows:—

ANALYSES OF TWO SAMPLES OF ANTHRACITE

	Per Cent.	Per Cent.
Fixed carbon	89.00	75.00
Volatile matter	4.50	6.00
Sulphur	0.50	2.00
Ash	4.00	15.00
Moisture	2.00	2.00
Total	100.00	100.00

For canal, river and coasting vessels, whether for business or pleasure, coalite may become the *beau ideal* fuel for gas propulsion.

But the object in view of the marine engineer is so to design his plant that the more common forms of coal may be utilized without previous preparation.

Plants suitable for the above mentioned special fuels would become

FIG. 6.—THE GAS-DRIVEN BATTLESHIP OF THE FUTURE. SHOWING NO FUNNELS NOR DECK OBSTRUCTIONS, SO THAT ALL THE GUNS CAN FIRE ON EITHER BROADSIDE, FORWARD OR AFT. AS PROPOSED BY MR. JAMES MC KECHNIE AND THE AUTHOR

unworkable if loaded with a common bituminous coal having the following composition:—

	Per Cent.
Fixed carbon	53.5
Volatile matter	40.0
Sulphur	0.5
Ash	5.0
Moisture	1.0
Total	100.0

And unless a gas plant can satisfactorily digest such a fuel, it cannot be classed as a "Bituminous Coal" plant, whether of the suction or pressure type.

Gas plants need not necessarily be arranged close to the engine room. Either of these systems can work satisfactorily at any distance from the engines not exceeding 100 feet, so long as the gas mains are well arranged and have few bends. As a matter of fact, the long pipes act as a reservoir and cooler from which the engine draws its charge, so that a continuous flow of gas from the producer is maintained and there are no serious heat losses, as would be the case with long steam pipes. This allows of considerable elasticity in arranging positions of engines and plants and has especial advantages for battleships.

Whilst acknowledging that the Körting, Oechelhäuser and Vogt vertical gas engines have many admirable features, the author must admit his preference for the "Otto" cycle being, in his opinion, specially adapted for marine work. On land the reliability of gas engines has recently been proved in the report for 1906 by Mr. Michael Longridge, who compares with steam engines in his list of breakdowns. The following are his figures:—

Breakdowns steam engines, 1 in 8.1.
Breakdowns gas engines, 1 in 12.4.

The principal reasons for these results are:—

1.—Gas engines have fewer parts than steam engines.

2.—These parts are on the average much smaller when compared with steam engine parts.

3.—Gas engines cannot habitually be subjected to stresses much heavier than the parts were designed to bear.

The various types of engines which must shortly be brought into competition in the arena of marine propulsion may eventually give place to the gas turbine, when our chemists have discovered new processes for hardening and preserving metals when subject to high temperatures and stresses.

Mr. James McKechnie states, in a remarkable paper delivered this year before the Institution of Naval Architects, that at Messrs. Vicker's Sons & Maxim's works there have been constructed internal combustion marine engines of a power equivalent to about 40,000 indicated horsepower after three or four years of continuous research work. The experiments have led to the adoption of a two-stroke cycle gas engine possessing satisfactory features, which may be worked either by producer gas, heavy oil or compressed air. It may be made reversible as easy as the steam or compressed air engine. He also says it is possible to use it in conjunction with pressure gas generators, which deliver their gas direct to the engines, as there is no necessity to pass it through any scrubber or other cleaning apparatus. An important feature in connection with this engine is that it may be worked by either gas or heavy oil, so that in the case of battleships or other large vessels the coal may be stored in the bunkers and the oil in the double bottom. This gives a duplication which is always desirable. The change from gas to oil may be made almost instantaneously. With oil the engine may be started when cold within a few minutes. This would be an important tactical advantage in warships. The compressor and producer plants are governed automatically according to the consumption of the propelling engines.

In his address before the British

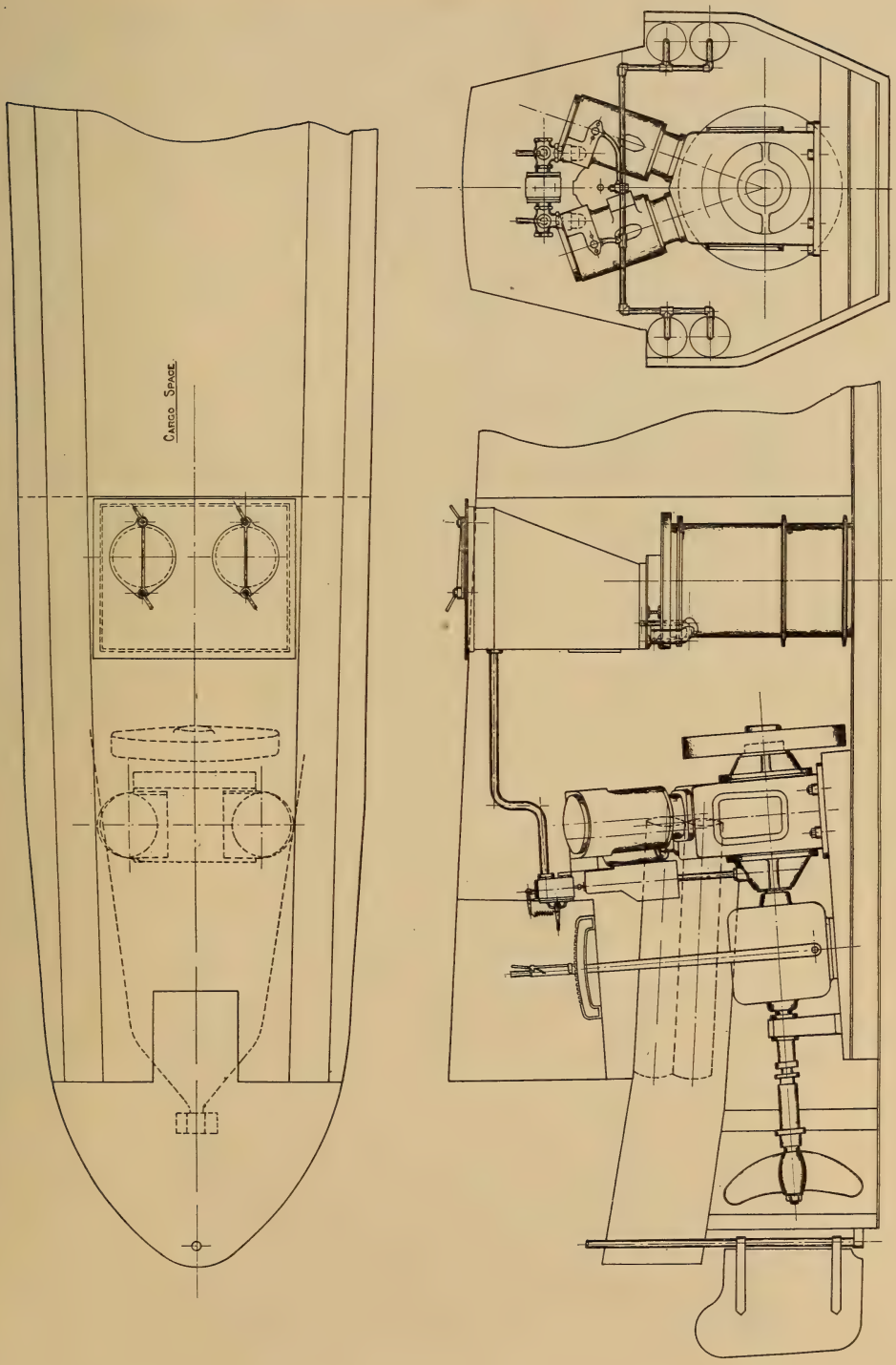


FIG. 7.—SUCTION-PRODUCER GAS PLANT AND ENGINE FOR CANAL BARGE. BY MESSRS. CROSSLEY BROS., LTD., MANCHESTER

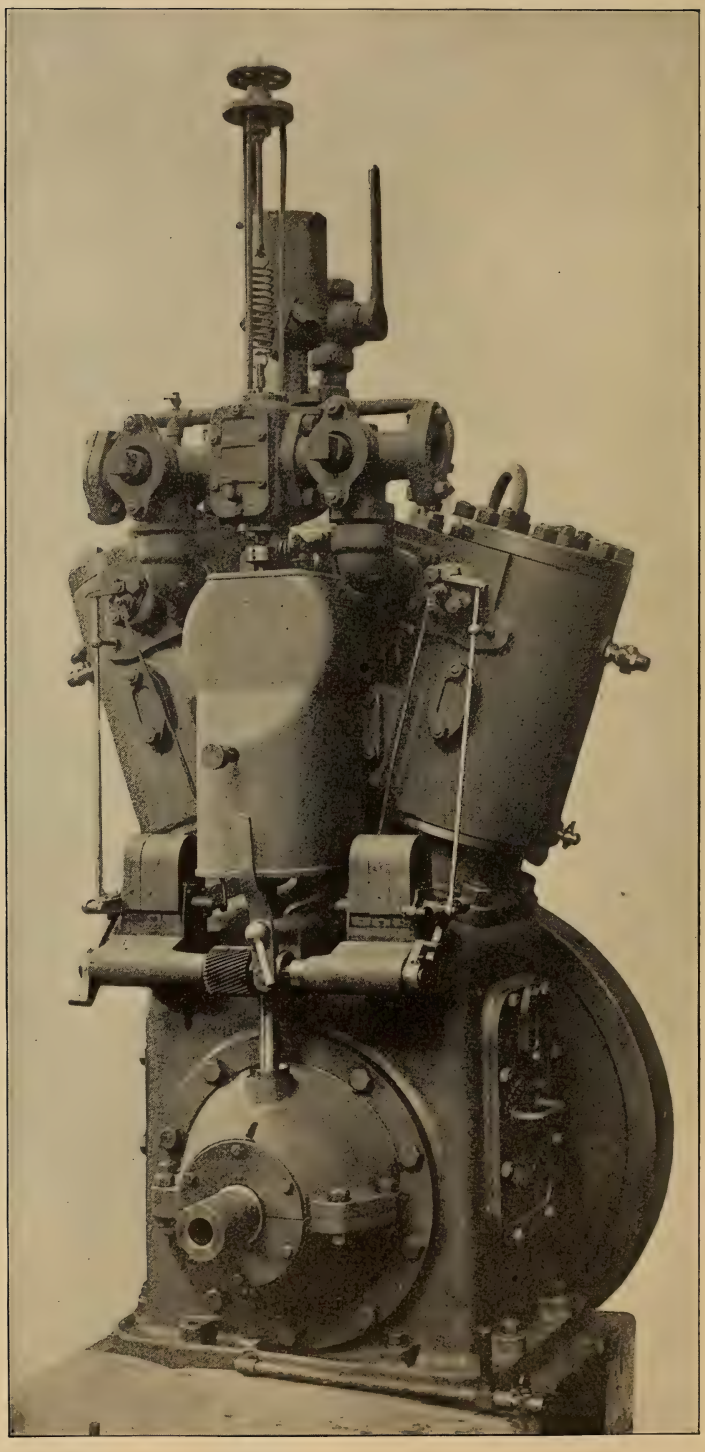


FIG. 8.—ENGINES OF CROSSLEY CANAL BARGE OPERATING WITH SUCTION GAS PRODUCER

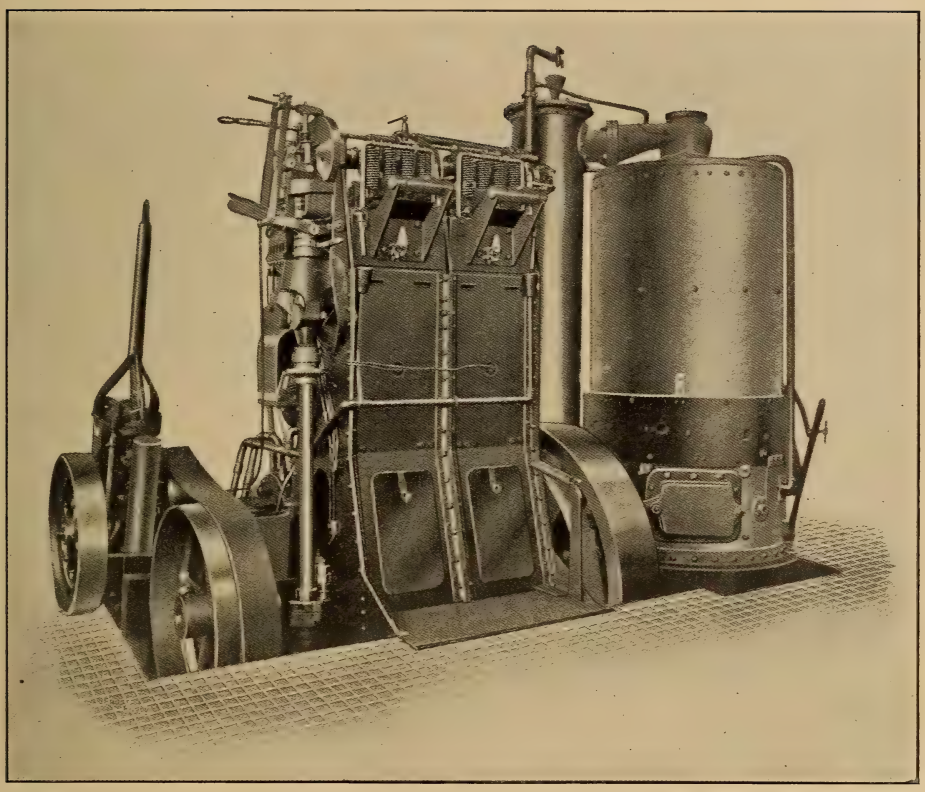


FIG. 9.—THORNYCROFT'S SUCTION GAS PLANT FOR MARINE PROPULSION, CAPITAINE SYSTEM

association this year, Mr. Dugald Clerk criticises Mr. McKechnie's paper, on the assumption that it advocated the adoption of a 16,000-HP. gas engine unit in a proposed battleship.

From the paper it is apparent that this power is split up into four or more gas-engine units, having six cylinders each. These engines are quite within the range of present-day practice. Similar engines are successfully at work on shore, and following investigations made by M. Letombe, the splitting up of the total power does not increase the cost per BHP. of large gas engines, as would be the case with steam engines.

Comparing steam-driven and oil-driven torpedo-boat destroyers having a speed of 30 knots, Mr. McKechnie states that the oil-driven vessel can carry a heavier armament when compared with the steam-driven vessel of same length and displacement, and also has a radius of action six and one-half times greater than that of the steam-driven destroyer at full speed; also the increase in space for the accommodation of the crew on the oil-driven vessel is another important point in favour of the internal-combustion engine, and this may be similarly applied to the gas-driven vessel. This change-over from heavy oil to gas has been in vogue for several years and is a valuable feature of the gas engine. A simple three-way cock having one port to the engine, a second to the producer, and the third to the oil vaporiser or carburetter is all that is required, so that by turning the handle over from one position to the other the engine will be driven either by gas or oil at will without showing any perceptible change in speed.

Illustrations Figs. 7 to 10 show Messrs. Crossley's and Messrs. Thornycroft's suction gas plant installations for marine propulsion. Both these types have been put under exhaustive tests and are already upon the market for river, canal and coast vessels. As a result of extensive experiments, trials and modifications, extending over several months, in order to ensure compatibility with ordinary working conditions, these plants have been evolved, and under the most severe tests have proved more than three times as economical in fuel as an ordinary marine steam equipment, while needing much less attention when in use. These plants consist of a suction gas producer in which the gas is generated, an internal combustion engine worked on the usual "Otto" cycle. Coke, anthracite coal or charcoal may be burned in the producer, and the gas is generated from a mixture of air and steam which is drawn through the incandescent fuel by the partial vacuum created by the outstroke of the piston in the engine. The gas is generated only as required, thus no gas-holder is necessary and there is no danger of explosion. Moreover, only a small floor space is required. There is no chance of leakage of gas, as the whole producer plant works at a pressure below that of the atmosphere. Gas is produced only as it is needed by the engine, and in quantities to suit the varying loads. In these plants the heat efficiency compares most favourably with the best compound condensing steam engine, being 23 per cent., as compared with only 11 per cent. for the steam engine, which proves that the gas plant consumes about one-third the fuel which would be used by a steam engine and boiler of the same power. Comparative tests made with two vessels, one fitted with a suction gas plant and the other with a steam triple-expan-

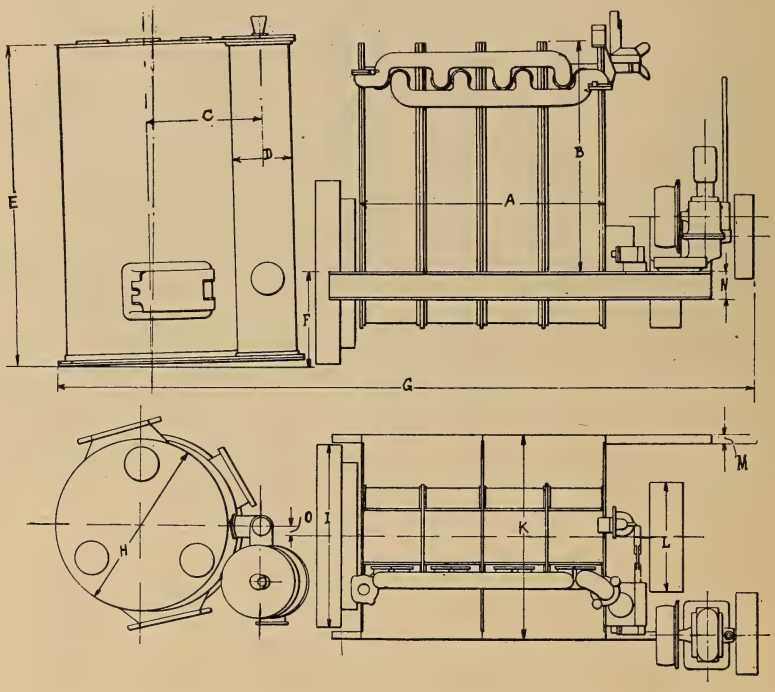


FIG. 10.—OUTLINE ARRANGEMENT OF THORNYCROFT SUCTION PRODUCER GAS MARINE ENGINES

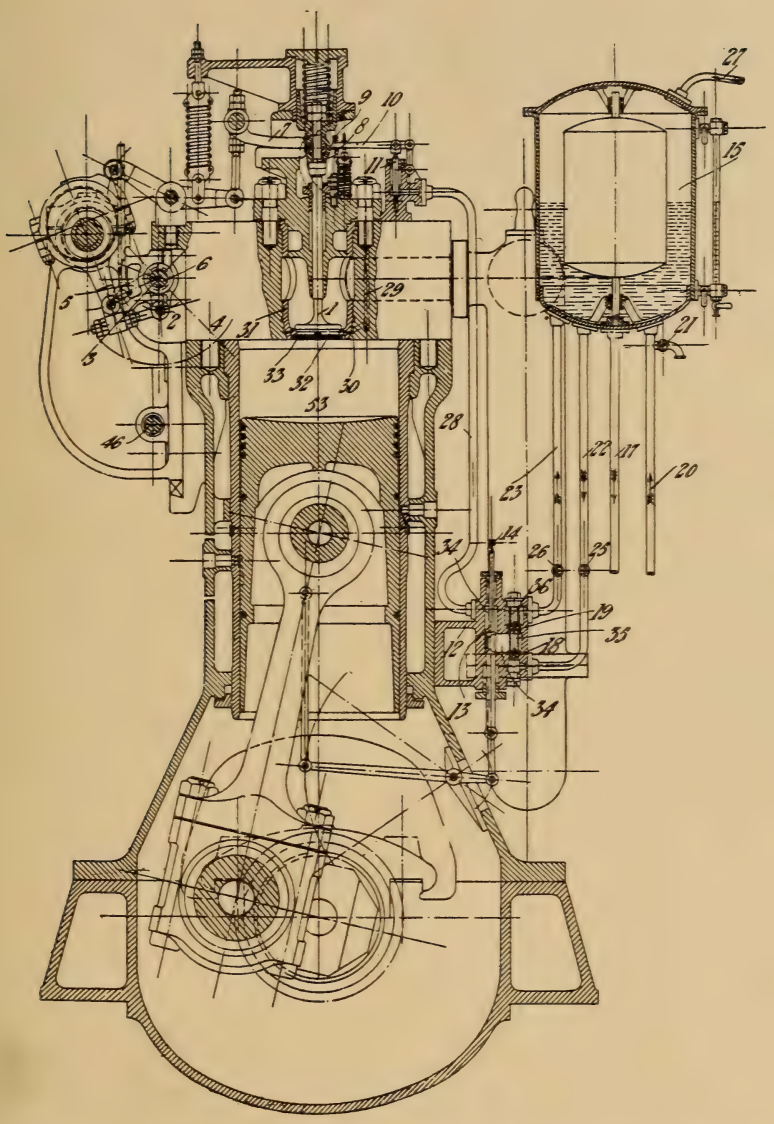


FIG. 11.—THE VOGT MARINE GAS ENGINE FOR LIQUID OR GASEOUS FUEL. REVERSIBLE TYPE. VICKERS, SONS & MAXIM

sion engine of the same power, proved that when the pull at the towing-meter was about equal the fuel economy of the two boats were as 1 to 3.44 in favour of the suction gas plant.

Messrs. Thornycroft have furnished some particulars as to the running of the *Emil Capitaine* at the reliability trials in the Solent in 1906, when she was awarded a special gold medal. The hull is built of galvanized steel plates and has a length of 60 feet with a beam of 10 feet. She is fitted with the Thornycroft producer gas plant and four-cylinder engine, embodying improvements tending to increase fuel economy. The engine gives 70 brake-horse-power, enabling the vessel to travel at a speed of 10 knots.

During the trials the fuel was care-

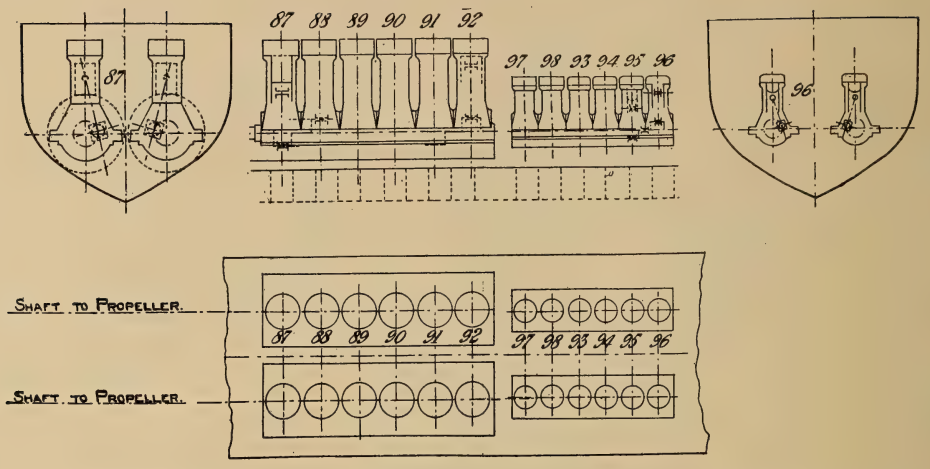


FIG. 12.—VOGT MARINE 6-CYLINDER GAS ENGINE, WITH SEPARATE CHARGING PLANT. ENGINES MAKE 300 TO 400 REVOLUTIONS, PUMPS MAKE 1,000 TO 1,500 REVOLUTIONS

fully and officially weighed, and it was found that the consumption for twenty-four hours, including lighting up and burning down, as well as ten hours running at about two-thirds power, was approximately 4 cwt. only, thus giving the consumption (reckoning the whole of the fuel as used for the generation of power in running time) of under 1 pound of fuel per brake-horse-power per hour.

Fig. 7 shows the canal barge *Duchess,* 71 feet 6 inches long, with a draught of 3 feet 6 inches, when carrying her usual load of 20 tons. The speed in open water is 6 knots. This barge recently made an extended tour through the British canals, from Chiswick to Manchester and back, a distance of more than 600 miles, including demonstration runs. In addition to being loaded, she towed an ordinary loaded canal barge and ran very satisfactorily during the trip. The total amount of fuel used during the forty days the engine was running was 5 tons 1 cwt. A sister vessel to the *Emil Capitaine* has recently been built to the order of Messrs. Wm. Beardmore & Co., Ltd., of Glasgow, for use in connection with their works on the Clyde, where she has been running since the beginning of 1906, on Scotch anthracite costing 12s. 6d. per ton.

Illustration (Fig. 11) shows the marine gas engine adopted by Messrs. Vicker's Sons & Maxim in their experiments. This engine has an explosion in each cylinder once in every revolution and has been very carefully designed and elaborated by Mr. Adolf Vogt, of London. A charging apparatus is required to force the charge at the right time into the cylinder, whereas, in the Otto type gas engine, advocated by the author, the engine itself draws in the charge on the suction stroke and fires it at alternate revolutions, requiring no charging apparatus, the engine itself being its own pump at alternate strokes. There remains a wide divergence of opinion among gas engineers as to whether the two or four-cycle engine is the better. In the author's opinion, the cooling effect in the Otto cycle engine by the interposition of the suction stroke adds very considerably to the life of the engine and obviates the necessity for any external charging arrangement. By reducing the average working temperature of the cylinder walls to within reasonable limits the somewhat complicated castings forming the breech end, liner and water-

jacket cannot be so severely strained by the expansion and contraction of the metal in heating and cooling as must be the case with the single cycle engine, in which no cooling stroke is interposed. Also the lubrication to the piston has a much better chance and will not so rapidly carbonize and form deposit in the cylinder, leading to pre-ignition and other troubles. For a vertical marine gas engine with cylinder 20 inches in diameter and over, working on the two-cycle system, it would be imperative to have the piston water-cooled. Therefore, after all, is not the tandem Otto vertical gas engine the simpler form of mechanism, giving an impulse for every revolution on the crank-pin with the stuffing-box and piston rod between the two cylinders, and being a self-contained unit, not dependent on any external apparatus? However, Messrs. Vickers' Sons & Maxim doubtless know what they are about. They have carried out careful experiments for a number of years with the Vogt engine, and it is hoped that shortly they will be in the position to give a practical demonstration of its qualities on the open sea.

The vessel fitted with a 500-HP. gas engine and plant by Messrs. W. Beardmore & Co., Ltd., has recently had two runs on the Firth. Mr. W. W. May writes "that as a tool the engine works with every satisfaction, but, as you are doubtless aware, there is much to improve on after a maiden trial"; also Mr. Capitaine has, I am informed, applied a gas engine and plant of 300 HP. to a towing vessel on the Rhine.

The evolution of marine gas propulsion can be safely left in the hands of well-tried and experienced firms such as are now engaged in it. Almost without exception the failures that have cast a shadow over the gas engine world have been the result of attempts carried out by those having little gas engine experience.

Gas and oil engines are essentially high-speed engines; speed is necessary to obtain their greater thermal efficiency over other types of heat engines. As a consequence, the propellers of a marine gas installation are small and work deep in the water, as is the case with the high-speed marine steam turbine.

In a recent paper the Hon. C. A. Parsons says:—"In turbine-propelled vessels the screws, owing to their reduced diameter and great depth of

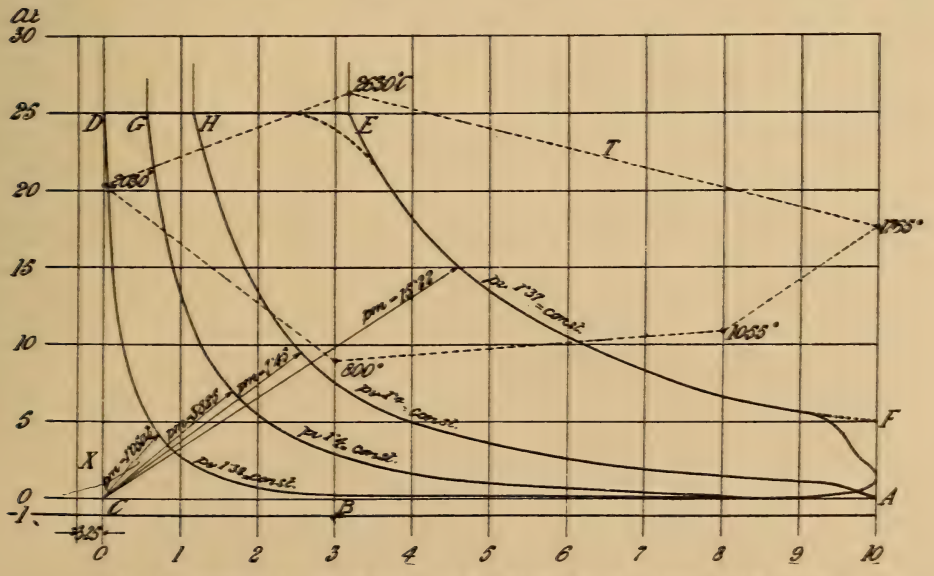


FIG. 13.—THEORETICAL DIAGRAM OF THE VOGT MARINE INTERNAL-COMBUSTION ENGINE

immersion, never race, and full steam can be maintained in all states of the sea with absolute safety to the machinery. That the revolutions are very little increased even in exceedingly rough water, is proved by the fact that no case has yet been recorded of the safety cut-out being brought into action in any vessel on service should the full-speed revolutions be exceeded by from 5 to 10 per cent."

The author confidently anticipates that the same unique results will be attained by the high-speed, small diameter, deeply immersed gas-driven propellers of the future. Illustration (Fig. 14) shows a vessel with gas-driven propellers which are 6 feet deeper in the water than the steam-driven, slow-speed propeller now on the vessel; not only is there less fear of cavitation, although rotating at a greater peripheral speed, but there is less chance of the blades breaking into the surface water and carrying round and down with it air which aggravates the racing trouble.

One of the chief objections raised against the system of gas propulsion advocated by the author was the difficulty that would be experienced in controlling a ship having a number of gas engine units. As a matter of fact, that difficulty does not really exist, and has been faced and overcome in the steam turbine vessels that are coming more and more into demand. In the *Carmania* there are three independent units, in the *Dreadnought* and *Lusitania* four independent units, which can be stopped, started or reversed at will. In these vessels the whole plant is controlled from a starting platform above the engines, where the engineer in charge has the telegraph, telephone pressure gauges and levers grouped for each engine unit, similar to a switchboard, and there he receives his instructions from the bridge as to which engine to stop or put ahead or astern. The officer in charge of the bridge practically manipulates the engines to suit the special circumstances of the vessel at the time; so that the employment of multiple gas units in the gas-driven vessel of the future is simply following on the lines adopted by present day turbine engineers.

The author is a strong advocate of the suction principle being maintained for marine purposes as against the pressure principle, insisted on by some authorities. With the suction plant, as has already been noted, the gas is generated in the producer and passes into the engine cylinder at a little below atmospheric pressure, so that if through the straining of the ship any leakage of the pipe should develop, no external difficulty would be experienced, as would be the case with steam pipes, for at the leak air would be drawn into the gas pipe, and so long as the engine was sucking the gas there would be no leakage of gas into the vessel. The small quantity of air drawn into the gas main would certainly dilute the gas, but unless the leak was very serious there would be no possible danger of an explosion or back-fire. And even when leakage occurred, when the engine was stopped, it could not amount to much, as the producer for the time being is practically put out of action, the leakage being sufficient simply to give warning by the smell of gas that the pipe needed attention.

The method of governing best suited for the marine gas engine is by the throttle, which can be controlled in a very simple manner either by the engineer in charge, or by the hand-governor or pendulum mechanism arranged to prevent any possible racing of the engines, when the ship is plunging. When the engineer receives a message from the bridge to go three-quarters or half speed or slow, it is only necessary to close down the throttle valve on each engine or to any one engine delineated on the telegraph, by this means shutting off the gas, and then if necessary the engine is brought to a standstill and reversed by compressed air from storage tanks. By this means

S. S. "Lord Antrim"
owners
The Irish Shipowners Co Ltd
Belfast

Vessel Built by Workman Clarke & Co Ltd – Belfast
Gas Engines & Gas Producer by A. V. Coster Esq – Manchester
Classed Lloyds 100 A1. Three Deck Rule

Length 375 – 3 Breadth 47. 2 Depth 28.85
Coal Bunker Capacity 1075 Tons
Estimated Speed with 5 Propellers 15% Higher Efficiency 14·26 Knots per Hour
Total Number of Knots 16826

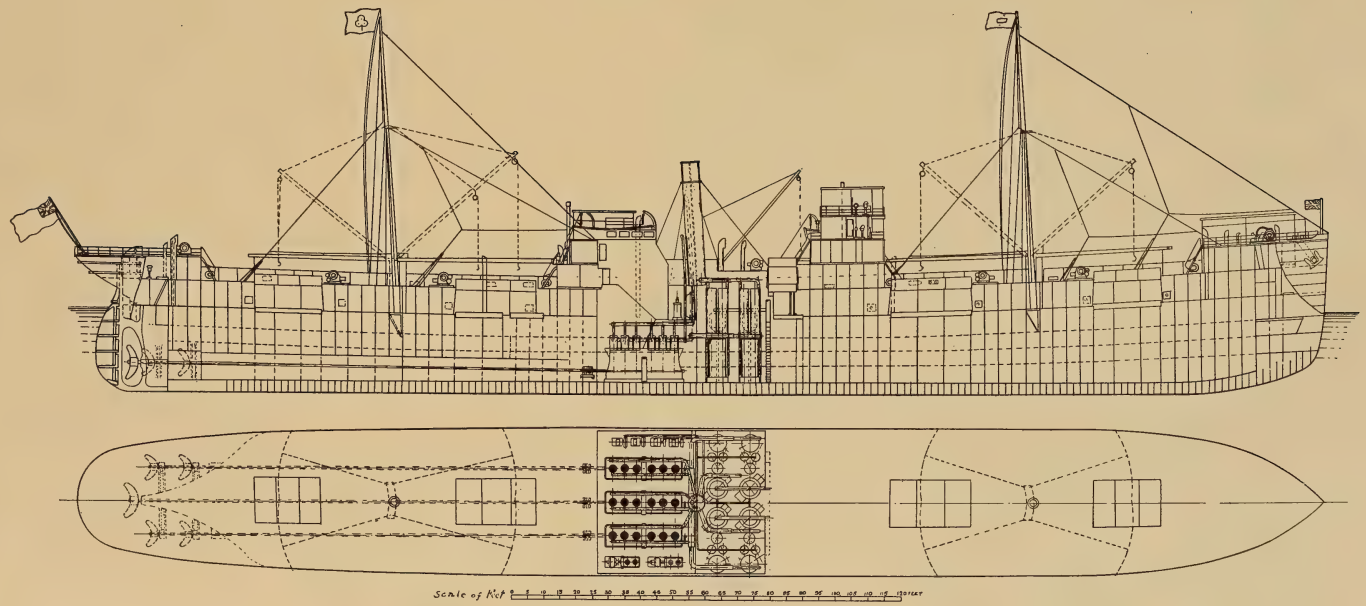


FIG 14.—GAS-PROPELLED SHIP "LORD ANTRIM," WITH 2,400 HORSE-POWER GAS ENGINES AND PRODUCERS. ARRANGED BY A. VENNELL COSTER, MANCHESTER

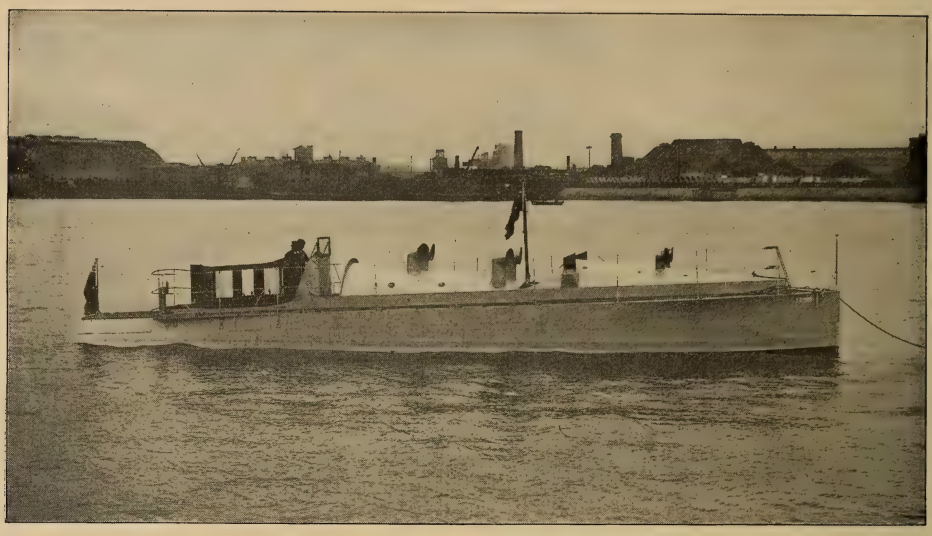


FIG. 15.—YARROW-NAPIER INTERNAL-COMBUSTION TORPEDO BOAT

the author does not anticipate any greater difficulty than was at present experienced with reciprocating steam engines in starting, stopping and reversing.

The Admiralty have an increasing number of war vessels with engines of the internal combustion type driven by heavy oils, the engines being used for auxiliary purposes. On H. M. S. *Dreadnought,* where the high-speed plant are steam turbines, the cruising plant steam reciprocating engines, it is worthy of note that all the minor engines, about twenty, are oil engines of the four-cylinder Diesel type, each engine representing about 160 I. H. P. These engines work on the "Otto" cycle. Messrs. Yarrow & Co. have built several torpedo boats and submarines driven by internal-combustion engines. A torpedo-boat by this firm, length 60 feet, beam 9 feet, attained a speed of 24-25 knots per hour. Comparing similar torpedo-boats having internal combustion engines versus steam machinery, the following figures show the superiority of the internal combustion engine. See Fig. 15.

The Yarrow-Napier internal combustion engine torpedo-boat referred to has five sets of four-cylinder engines, i. e., twenty cylinders in all, $6\frac{1}{2}$ inches diameter by 6 inches stroke, running at 1,100 revolutions per minute; the centre engine only is reversed by a clutch. The three propellers have three blades of manganese bronze, which have about 20 per cent. slip.

YARROW-NAPIER TORPEDO BOAT WITH INTERNAL-COMBUSTION ENGINES

Length = 60 feet.
Beam = 9 feet.
Speed, light, $25\frac{1}{2}$ knots.
Speed with 3 tons, 24 knots.
Radius of action at full speed, 250 miles.
Fuel capacity, 1 ton.
Lifting weight for transport by rail, 8 tons.

YARROW TORPEDO BOAT WITH STEAM MACHINERY

Length = 60 feet.
Beam = 9 feet.
Speed, light, $19\frac{1}{2}$ knots.
Speed with 3 tons, 18 knots.
Radius of action at full speed, 108 miles.
Fuel capacity, 2 tons.
Lifting weight for transport by rail, 12 tons.

The speeds are given on the basis

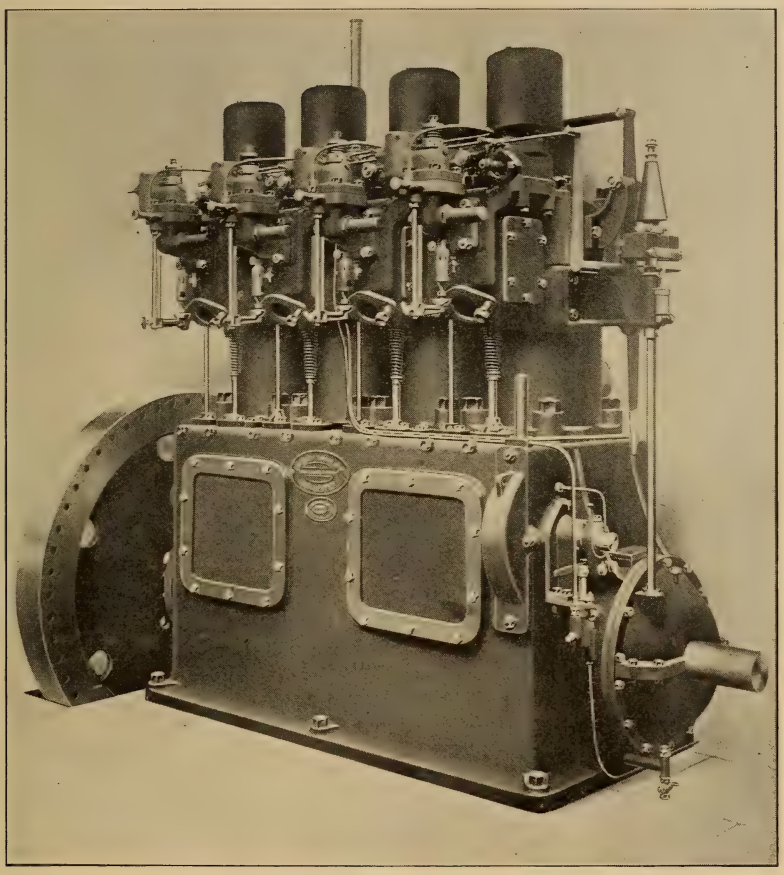


FIG. 16.—FOUR-CYLINDER VERTICAI OIL ENGINE FOR MARINE SERVICE. CROSSLEY BROTHERS, MANCHESTER

of both boats carrying a load of 3 tons. As in the motor torpedo-boats there is only one ton of fuel, as compared with two tons in the steam-driven boat, the motor torpedo-boat would be capable of carrying one ton more armament than the steam-driven boat. The load of three tons amply covers the weight of armament of torpedoes and fuel, and the above figures prove that with the same weight of fuel, petrol against coal, the internal combustion engine gives the vessel a radius of action nearly five times greater than the steam engine. It should be noted that a craft of this size and weight, namely, eight tons, can be transported with facility by rail from one coast to another, so that a port undefended one day

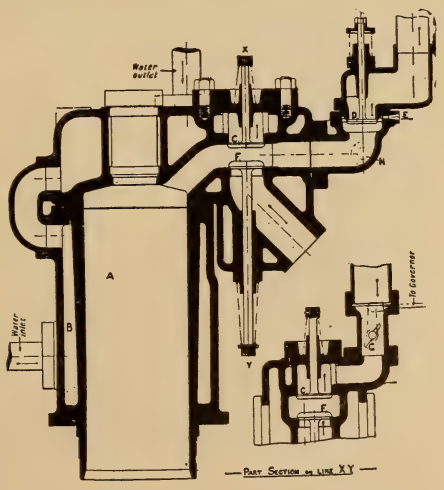


FIG. 17.—VERTICAL SECTION OF CROSSLEY OIL ENGINE

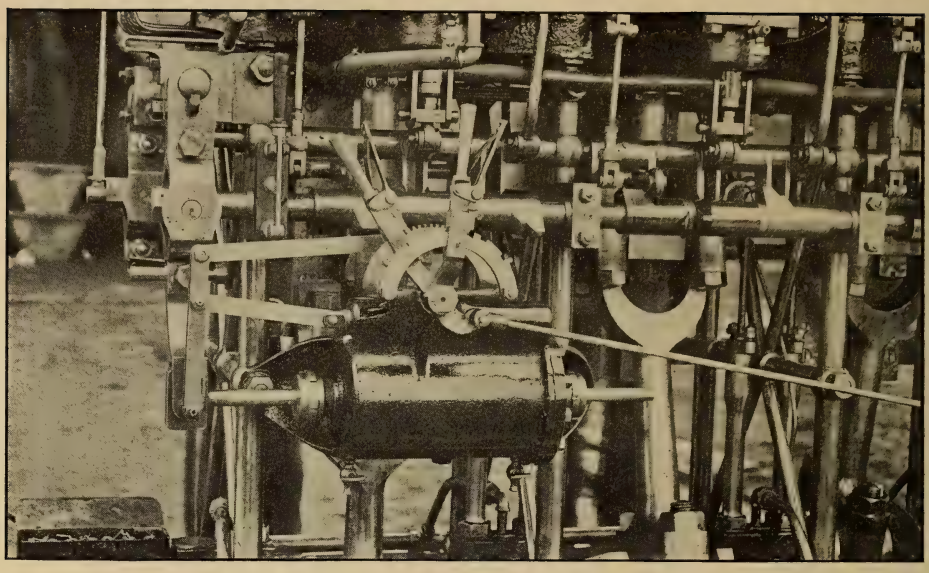


FIG. 18.—REVERSING GEAR OF 500 HORSE-POWER MARINE ENGINE. STANDARD MOTOR COMPANY

might be placed in a state of defence the next.

A four-cylinder vertical oil Crossley engine as supplied to the Admiralty is illustrated in Fig. 16. A section through the cylinder head is also given in Fig. 17, which shows arrangement of valves for special governing device by means of which the compression is increased when small charges are admitted to cylinder in order to ensure complete combustion. This has been eminently successful.

Many firms are now engaged in supplying gas and oil marine engines for launches, barges, coast-boats, trawlers, etc. The internal combustion engine using liquid fuel has already obtained a firm foothold in America for lake, river and canal traffic. As a rule, the engines used are of the Beau de Rochas or Otto cycle. The Standard Motor Company, of Jersey City, has built engines of 300 horse-power, and recently one having six double-acting cylinders 12½ inches diameter by 12½ inches stroke, developing 500 brake-horse-power on gasoline fuel. This engine is reversed by compressed air and has water-cooled valves, pistons, piston-rods and jackets. Demand is also being made for this system of marine propulsion in Great Britain. Two illustrations of the Crossley marine engines, Figs. 20 to 24, having two and four cylinders, show external design. These engines can run on any of the following fuels, and when necessary an engine can be arranged to change over without stopping from one fuel to another. The engines have single-acting cylinders, and powers range from ¾ to 50 brake-horse-power per cylinder.

FUELS SUITABLE FOR MARINE COMBUSTION ENGINES

1.—Gas from suction or pressure producers working on anthracite, coke or bituminous coal.

2.—Petrol, including all kinds of motor spirit, gasoline, benzine and naphtha spirit.

3—Alcohol or methilated or denatured spirit, and benzol or coal tar spirit.

4.—Paraffin or kerosene, including all kinds of petroleum, lamp oil.

5.—Oil gas from oils, fats, etc.

6.—Crude light and heavy oils.

There is a large field opening out

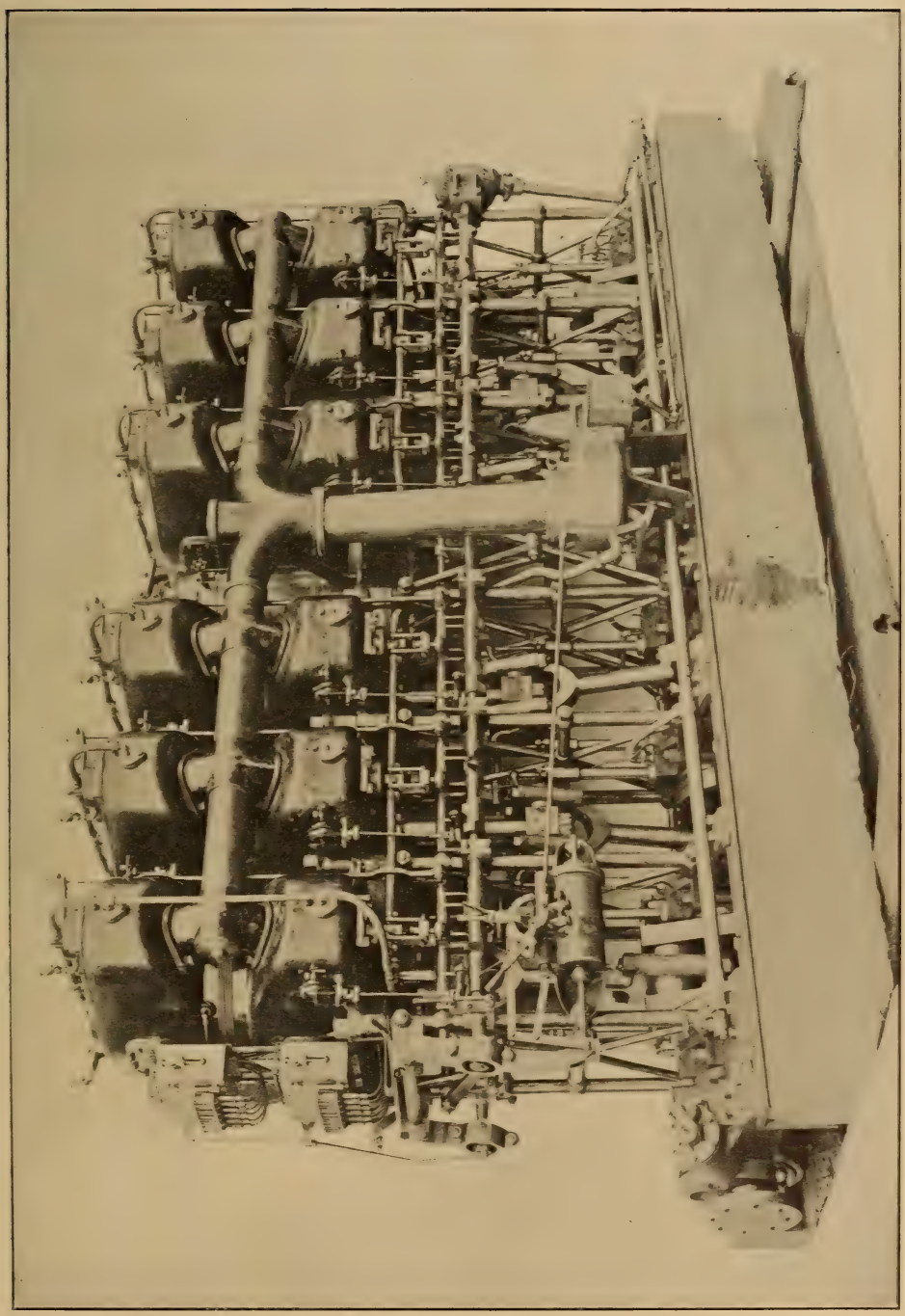


FIG. 10.—MARINE ENGINE OF 500 HORSE-POWER. STANDARD MOTOR CONSTRUCTION COMPANY, JERSEY CITY, N. J.

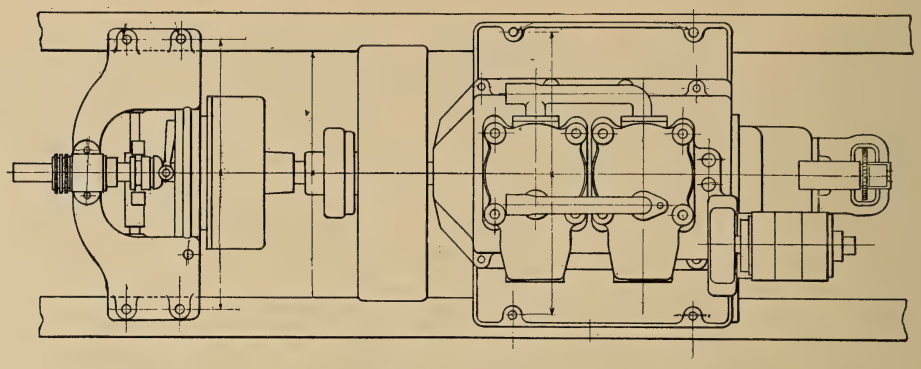


FIG. 20.—PLAN OF TWO-CYLINDER OIL ENGINE. CROSSLEY BROS., MANCHESTER

for similar engines on board sailing vessels, dredgers, fishing smacks and deep-sea trawlers for use in discharging cargo or for general hauling or lifting purposes, thus dispensing with the expensive, cumbersome and wasteful donkey boiler and steam engines consuming from 7 to 10 pounds of coal per indicated horse-power.

Important developments have taken place in the use of internal combustion engines for marine purposes of the vertical Diesel oil engine type. The inherent disadvantages in these engines, namely, non-reversibility and difficulty of speed variation, have been overcome by the use of electrical power transmission between the engine and the propeller. If the engine main shaft is fitted with a dynamo and the propeller shaft with an electro-motor, then the current received by the latter and generated by the dynamo, makes it possible to run the propeller in either direction: and also to regulate the speed to any amount required between full and stop, and this without disturbing the running of the engine. In several countries different applications of electrical transmission for propelling ships have already been made, the first by Messrs. Nobel Bros., of St. Petersburg. One of their vessels, the *Vandale,* a tank steamer of 1,100 tons displacement (see Plate No. 26) has been in service since 1903 carrying petroleum on the Volga and

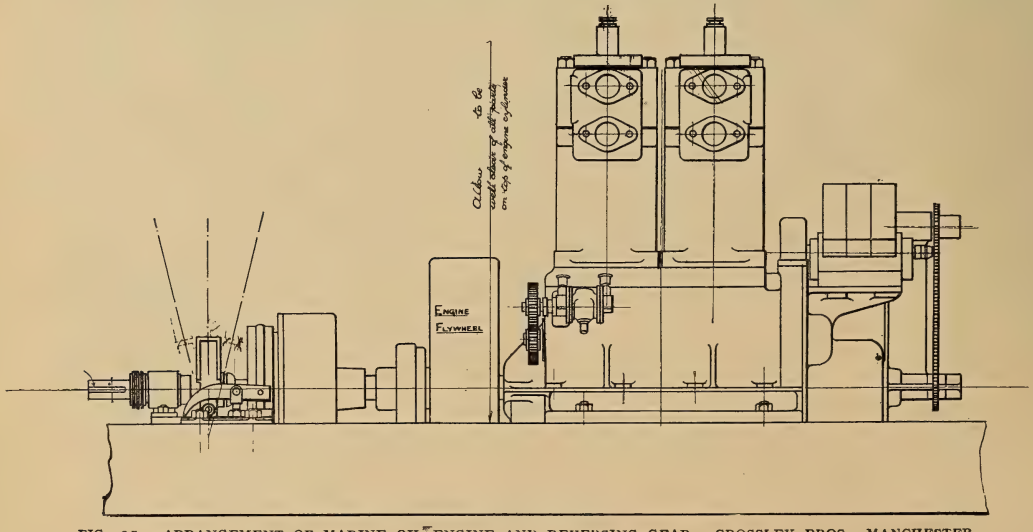


FIG. 21.—ARRANGEMENT OF MARINE OIL ENGINE AND REVERSING GEAR. CROSSLEY BROS., MANCHESTER

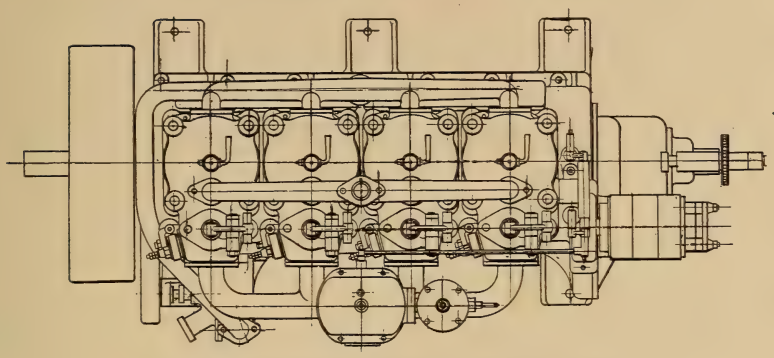


FIG. 22.—PLAN OF FOUR-CYLINDER MARINE OIL ENGINE

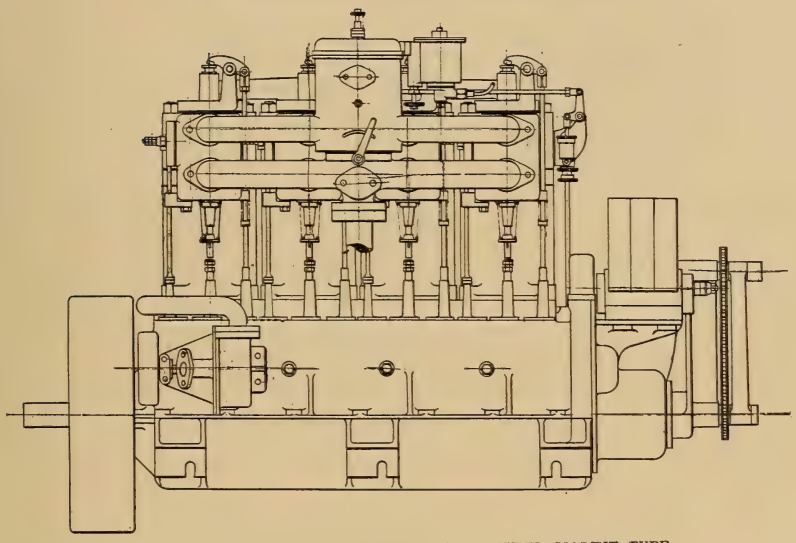


FIG. 23.—FOUR-CYLINDER VERTICAL OIL ENGINE, MARINE TYPE

the Caspian Sea. It can be seen that the propulsive plant in this vessel consists of three electrical groups installed amidships, each set comprising a three-cylinder oil engine of 120 HP. at 240 revolutions per minute, coupled to a dynamo generating a continuous current of 87 kilowatts at 500 volts. These three dynamos supply current to three electro-motors of 75 kilowatts fitted on the three propeller shafts. Each propeller may be worked independently by combinators placed on the navigating bridge; also each dynamo and electro-motor group may be regulated by modifying the excited current of the dynamo, which current is supplied by a small exciting dynamo fitted on the main engine shaft.

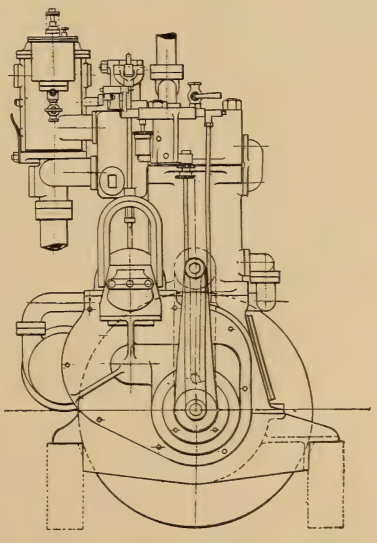


FIG. 24.—END VIEW OF MARINE OIL ENGINE

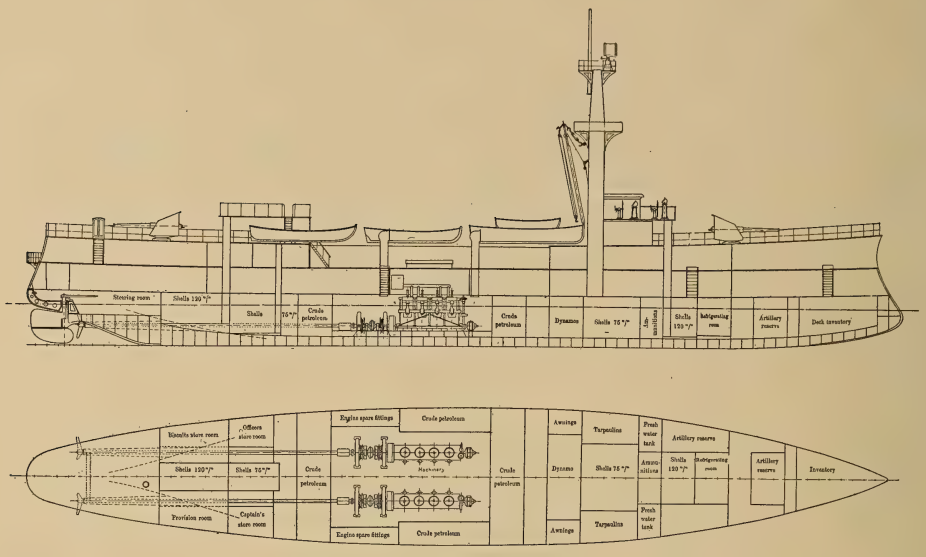


FIG. 25.—GUNBOAT FITTED WITH DIESEL-DEL PROPOSTO PLANT. 1,316 TONS DISPLACEMENT. 1,400 H.P SPEED, 13 KNOTS

The armature of the dynamo and of the electro-motor are united by direct and unchangeable connections. Monsieur A. Lecointe, of Brussels, who has been kind enough to supply me with this information, also states that this system of regulating the electro-motors offers the advantage of manœuvring the ship while acting on a weak current (the excited current), and consequently to dispense with large rheostats, which would be required if the electro-motors were operated, as is generally done, by modifying the main current. On the *Vandale* eight to ten seconds are sufficient to pass from full speed ahead to full speed astern. The generating groups, the electro-motors and the combinators are placed on board the ship in different positions, with the result that the engineers attending to the electro-generating group do not even know in what direction or at what speed the propellers are running. The whole control of the propelling gear is entirely in the hands of the navigating officer on the bridge, who can steer and manœuvre the vessel without transmitting any orders to the engine staff. This system of electrical transmission is applicable to any type of internal combustion engine, and some of its advantages are:—

First—That each propeller can be operated in either direction at any speed and without shock and more rapidly than when directly coupled to the driving engine.

Second—The control of the propelling mechanism can be placed entirely in the hands of the navigating officer, who is thus made absolutely responsible for every revolution made by each propeller, and thus the vessel can be manœuvred with greater ease and accuracy.

On the other hand, permanent electrical transmission has its disadvantages. The system necessitates large dynamos which occupy room and are expensive; for instance, on the *Vandale* the three oil engines weigh 48 tons and the electrical motors required for transmitting power to the propellers weigh 31.25 tons, or 65 per cent. of the engine weight. Also there are electrical losses of energy which amount to from 15 to 20 per cent. of the power transmitted, which necessitates larger propelling engines and consequently heavier cost

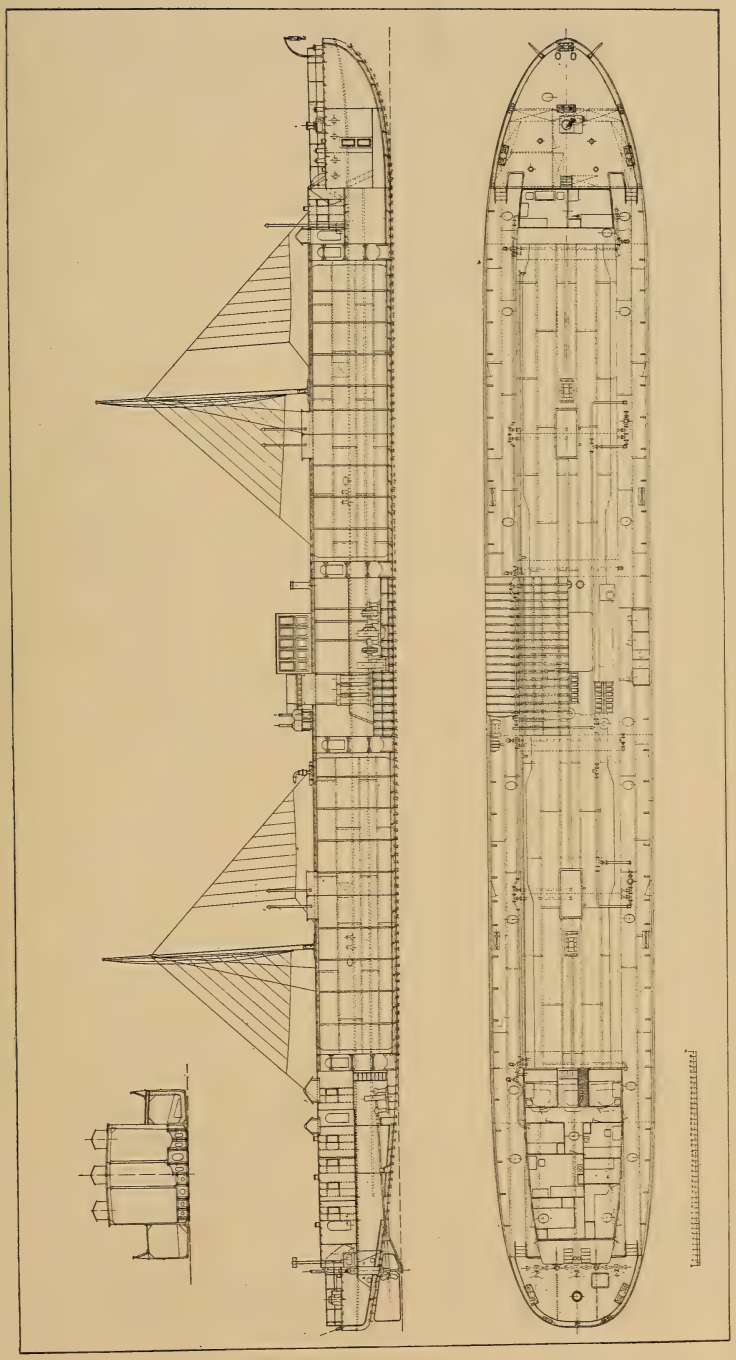


FIG. 26.—TANK VESSEL "VANDALE," FITTED WITH DIESEL ENGINES OF 360 HORSE-POWER. DISPLACEMENT, 1,150 TONS; SPEED, 8 KNOTS

in fuel. Again, such a plant is subject to deterioration and constant oversight and repair, which may be required at any time, and may possibly detain the vessel when on her voyage.

A system of electrical transmission which retains many of the advantages already enumerated and few of its disadvantages has been designed by Mr. Del Proposto, and has been successfully tested on several sea-going vessels, notably the *Sarmat* (see Plate 27) and the *Venoge*. The hull of the *Sarmat* is identical with the hull of the *Vandale;* the two vessels are only dissimilar in the internal arrangement of the propelling plant. The Del Proposto system applied to the *Sarmat* has been running since May, 1905, and has proved of considerable advantage over the electrical arrangement as applied to the *Vandale,* comparing weights on the *Vandale* 625 pounds per brake-horse-power, on the *Sarmat* 396 pounds per brake-horse-power. This reduction of weight, and therefore of cost, in the Del Proposto system, is due to the fact that the dynamo produces work only during the reversal or slowing down of the propeller, the normal power of the dynamo being only about half the full power of the engine. For driving the propeller full-speed ahead at full power the transmitting mechanism between engine and propeller is an electro-magnetic or mechanical clutch, which can connect or disconnect the two shafts at will. The working of the system is as follows:—

When the vessel has to run at a reduced speed or with propeller reversed, this clutch is disconnected and the propeller is driven by means of the dynamo attached to the engine transmitting electrical power to the motor mounted upon the propeller shaft. This can be clearly seen on reference to Plate No. 27. When the vessel is being driven full speed ahead the rotating parts of the dynamo and motor do not produce any current and simply act as mechan-

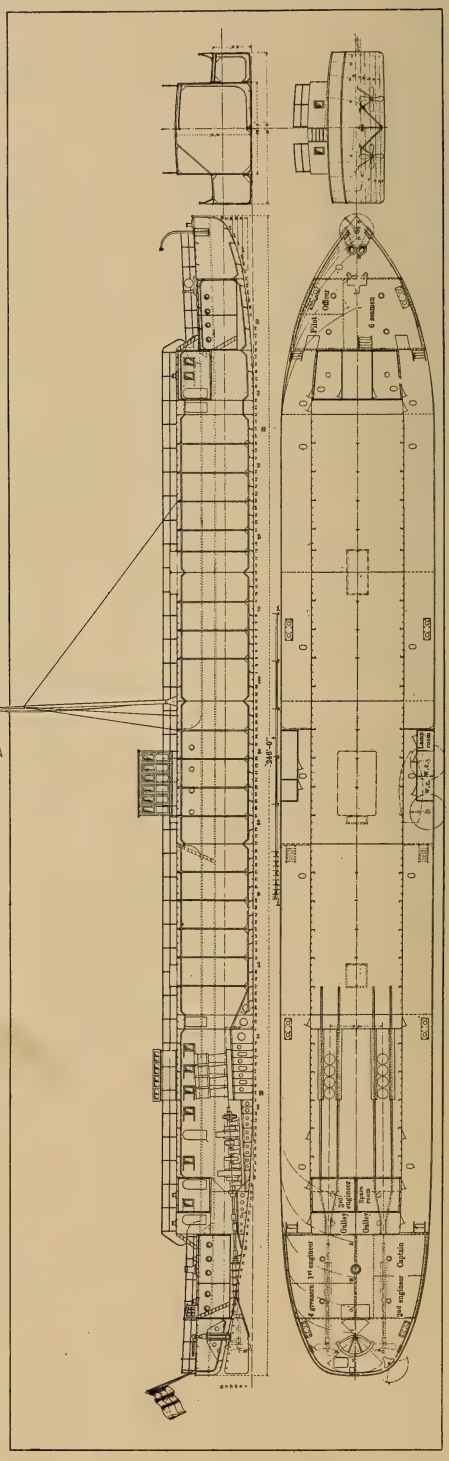


FIG. 27.—TANK VESSEL "SARMAT," FITTED WITH DIESEL ENGINES AND DEL PROPOSTO TRANSMISSION. DISPLACEMENT, 1,150 TONS; SPEED, 8.6 KNOTS

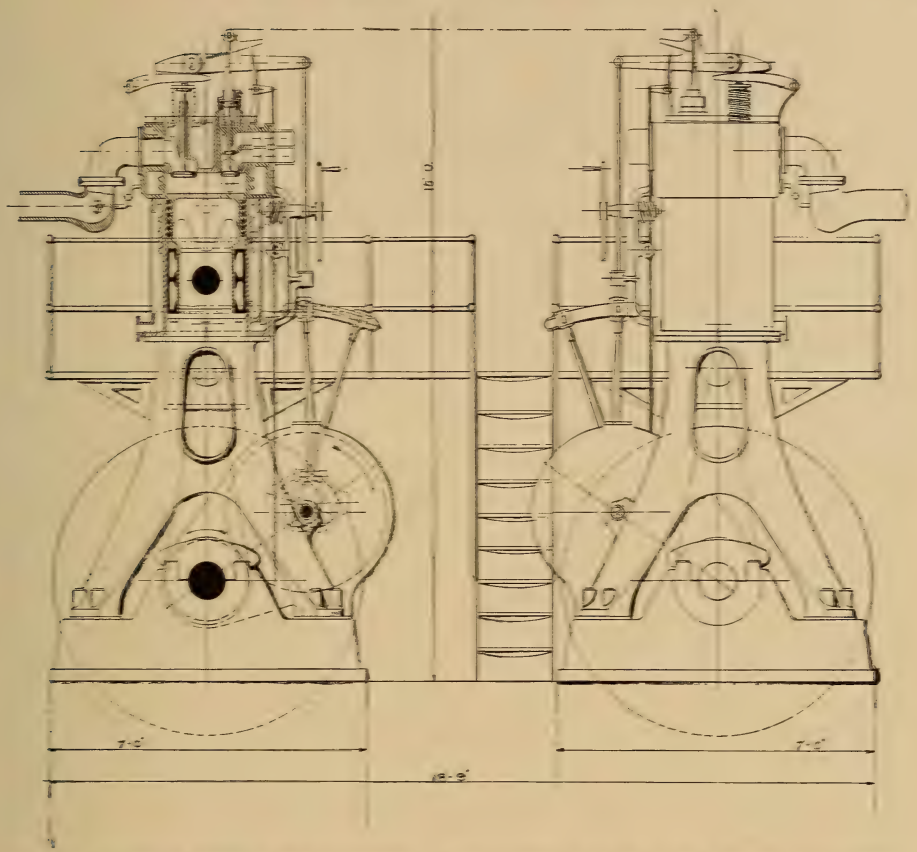


FIG. 28.—REVERSING MARINE TWIN GAS ENGINE. SIX CYLINDERS, 21-IN. BY 24-IN. STROKE. 250 REVOLUTIONS, 1,600 HORSE-POWER. A. VENNELL COSTER, MANCHESTER

ically rotated masses, the propeller being connected directly to the engine. The coupling, as has already been stated, may be mechanical or electro-magnetic; the former does not absorb much energy, and the latter about one-five-hundredth of the power transmitted, a negligible quantity. By this means, if anything, better results are obtained with a less costly plant than with the permanent electrical transmission, as seen on the *Vandale*. The *Vandale* has a speed of 7½ knots, while the *Sarmat*, with the Proposto system, attains over 8 knots.

This latter arrangement has many admirable features, especially the simplicity of control, and will undoubtedly be largely used in the future in connection with not only internal combustion engines using oil but gas as fuel. This system is also illustrated in Fig. 25, which shows a gunboat designed by Mr. K. Boklewsky, professor of naval architecture at the Polytechnic Institute, St. Petersburg.

The author, in conclusion, considers that the bona fide examples of vessels driven by internal combustion engines, as given in this paper, are sufficient to demonstrate that very real progress has already been made, and that, contrary to Mr. Dugald Clerk's diagnosis, ship propulsion by internal-combustion engines has already passed its "early infancy."

THE GASOLINE AUTOMOBILE

By Forrest R. Jones

One of the important applications of the internal-combustion engine, and probably the most widely apparent one to the general observer, is that of the mechanical propulsion of vehicles. The moderate size, high power, and general convenience of the combustion-eigine, burning gasoline or other light hydrocarbon fuels, has rendered it especially applicable to this service, and if anything were needed to convince the public of the practicability of the generation of power by the direct combustion of the fuel in the working cylinder, the modern motor-car should furnish that demonstration. Professor Jones examines the subject from the viewpoint of the mechanical engineer, versed in the details of machine design and at the same time familiar with the requirements of the vehicle upon the road. His discussion applies with especial force to the United States, where the condition of the roads demands even greater strength and correctness of design than in Europe, where the art of road-making has been carried to a higher degree of perfection, but the principles of correct mechanical design hold good in all parts of the world.—The Editor.

THE gasoline automobile is already developed to as great perfection as the steam railway locomotive, the electric railway car, or the marine engine. It requires more skill and a greater knowledge of materials and machinery to be a *competent* chauffeur in the broadest sense of the word, than to drive a locomotive or marine engine, including repairs in all cases. One doubting the truth of this statement may say that chauffeurs are not nearly so well trained in machinery as are locomotive and steamboat engineers, and speak the truth. The only wonder is that, in the hands of those as ignorant of the machines they drive, as reckless in their driving, and as negligent in their care as the majority of those who operate automobiles, the automobile has come out so well. The credit is due largely to a small proportion of skilled and conscientious men who have demonstrated how serviceable and durable an automobile can be, instead of showing in how many ways it can be strained, racked and torn to pieces. A study of the repairs that are made on the majority of cars, even including the best class, will carry forcible conviction that fully two-thirds of them would never have been required had the car been handled carefully and with good judgment. They are not due to any fault in the design or construction of the machine, or to the legitimate wear and tear of service. The rule of many a driver is to run his machine without inspection until something happens to put it in the repair shop.

The internal-combustion engine, the most vital part of the automobile, has been brought at least as near to perfection as any of the other major parts. It has completely demonstrated its superiority over other types for both touring and urban service. Even the physician has come to prefer it, despite the numerous stops to be made on his round of calls. The electric runabout still serves many of the latter, however, and for ladies who do their own driving, it is unequaled.

There is still abroad the cry that the ignition system of the gasoline or naphtha engine is uncertain in its action and cannot be relied on. There is no question that the experiences of many a careless, ignorant and inexperienced driver have been such as to amply justify him in his belief. But if the ignition apparatus is well made, properly installed and carefully cared for, it practically never gives serious trouble through any fault of its own. It is true that deluging the piston and cylinder with an immoderate bath of poor lubricating oil, or using an abnormally rich combustible mixture, may so foul the parts inside the combustion chamber as to allow the high tension current to pass

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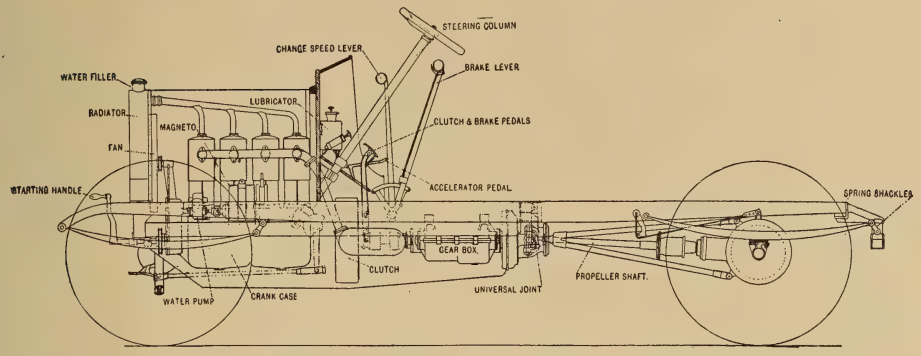
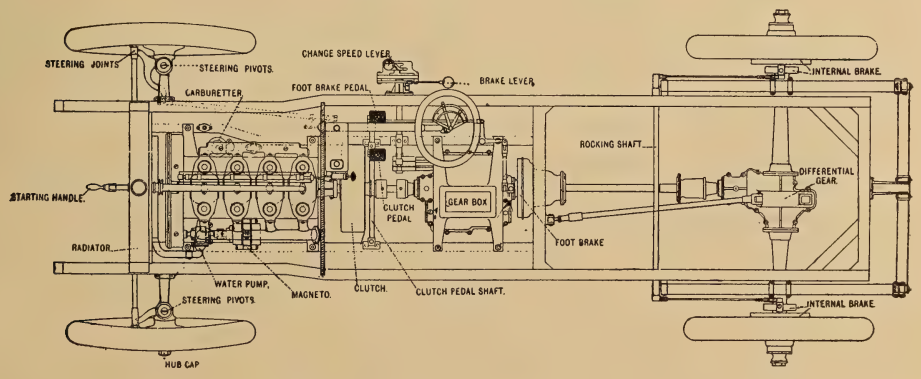


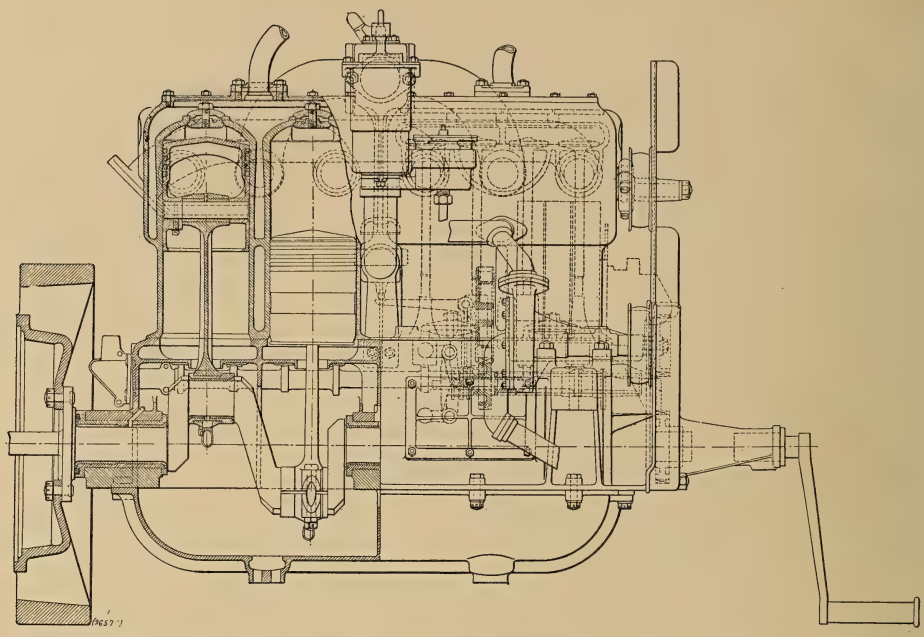
GENERAL ARRANGEMENT OF MODERN CAR WITH SHAFT DRIVING. HUMBER, LIMITED, COVENTRY

through the collection of oil and carbon covering the insulation of the spark plug, instead of sparking properly across the air gap, or prevent the contact points of the make-and-break low tension system from coming together metallically to close the circuit and draw an arc upon separation, but these are not faults of the ignition apparatus. Such troubles are readily eliminated by using the right quality and quantity of lubricating oil and properly regulating the proportions of fuel and air in the combustible mixture. The only serious trouble in the high tension system that cannot be forestalled is the breaking down of the spark plug insulation. To replace a defective spark plug with a new one requires but a few minutes at the most, however. In the low tension system, the contact points inside the combustion chamber sometimes oxidize and fail to make metallic contact. It is a short piece of work to clean or adjust them.

Ignition is usually accomplished in the low-priced cars by a battery of dry cells operating through an induction coil for each cylinder to produce a high tension jump spark. A storage battery is used instead of the dry cells in the slightly more expensive cars. The high tension distributer system, operated by either a battery or generator, does not seem to be growing in favour. The heavy service demanded of the single coil in a four-cylinder engine makes it difficult to keep the vibrator contacts from fusing and oxidizing. In the very high-priced cars, the high tension electric generator for the jump spark, or the low tension generator for the make-and-break system, is generally found. A storage battery or dry cells are often added for starting the



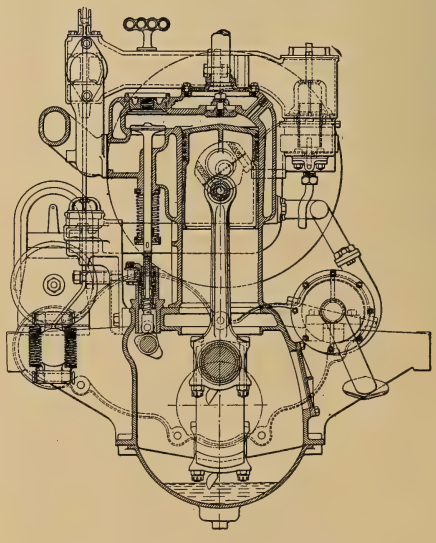
PLAN OF HUMBER 30-HORSE-POWER CHASSIS



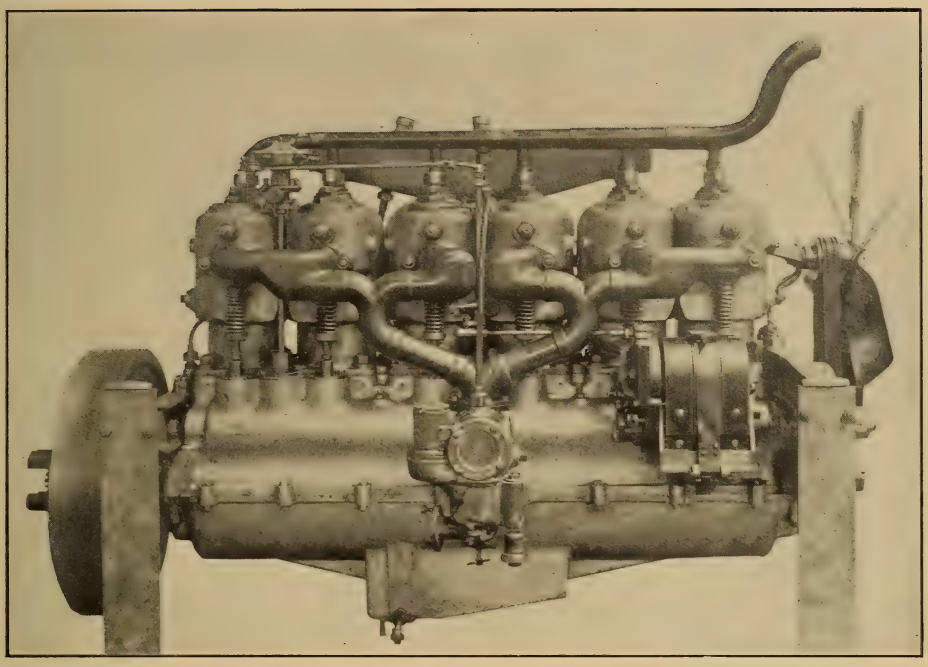
LONGITUDINAL SECTION OF SIDDELEY ENGINE. THE WOLSELEY TOOL AND MOTOR CAR CO., LTD., LONDON

motor on compression by firing the charge in one of the cylinders while the engine is at rest. Electric generators with permanent field magnets are far more extensively used than those with electrically excited fields. In some systems the storage battery is permanently connected to the low tension generator, after the method of using storage batteries in connection with electric generators for city lighting. The storage battery is thus always kept charged and ready for use. Not infrequently both the jump spark and the make-and-break systems are installed on the same engine. The idea is that only one shall be used at a time, but they can be put on together. The automobile engine designer is learning that platinum points for the contacts of the make-and-break system are neither necessary nor as good as steel contacts. The stationary gas engine designer learned this long ago. Two disks or washers of steel with their axes perpendicular to each other make the best of contact by pressing their edges together. When worn, new parts of their edges can be brought together by rotating them slightly on their fastenings. Their cost is negligible compared with that of platinum, and they are more satisfactory.

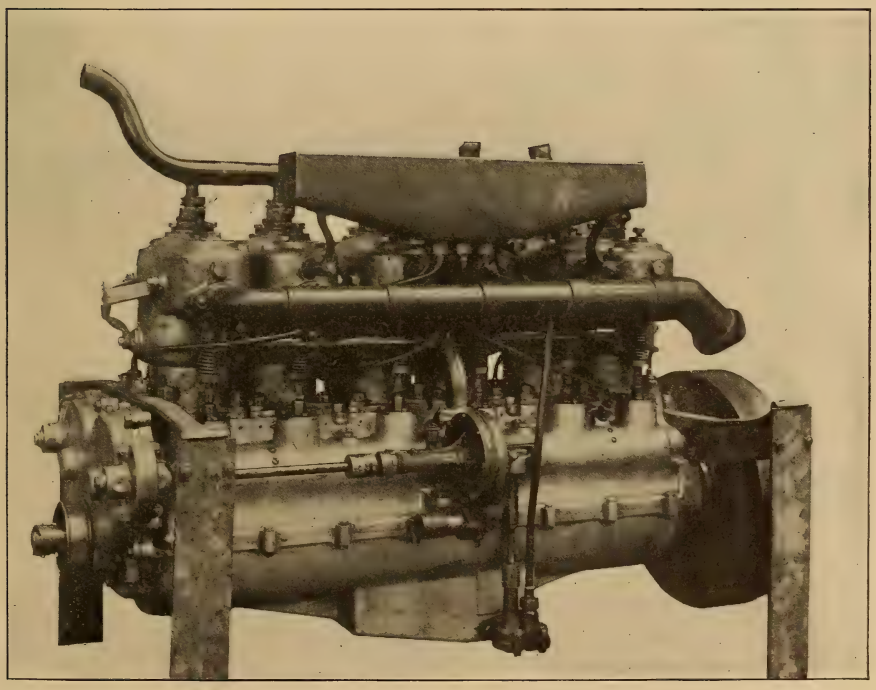
The "four-cycle" motor, in which the piston makes four single strokes during each cycle of events in one



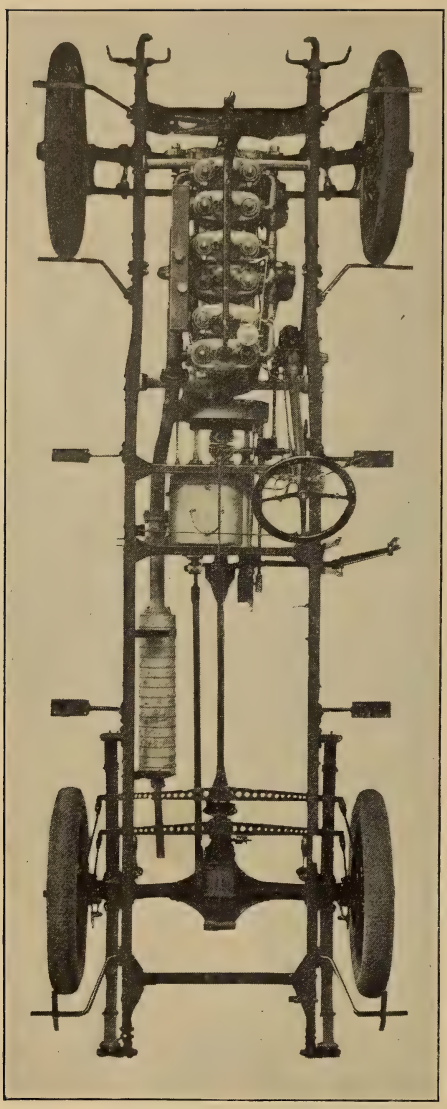
CROSS SECTION OF SIDDELEY MOTOR



SIX CYLINDER ENGINE OF GREAT ARROW CAR. RIGHT-HAND SIDE. THE GEO. N. PIERCE CO., BUFFALO, N. Y.



SIX-CYLINDER ENGINE OF THE GREAT ARROW CAR. THE GEO. N. PIERCE CO., BUFFALO, N. Y. LEFT-HAND SIDE



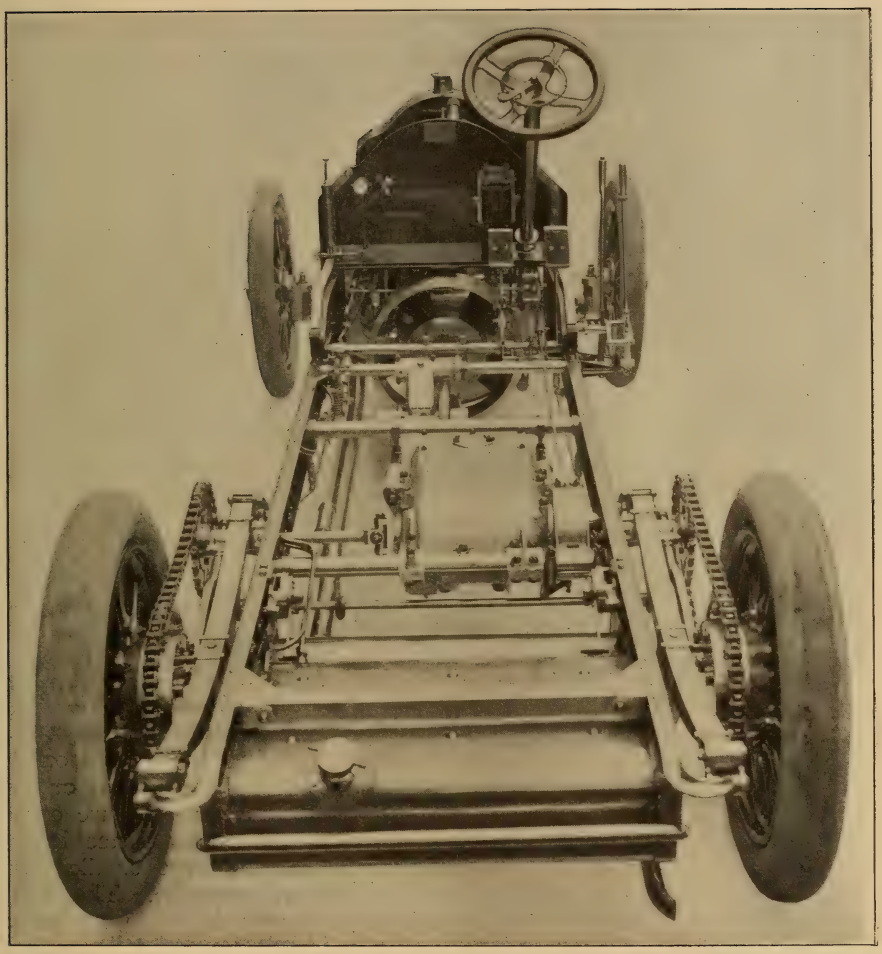
GREAT ARROW CAR. PLAN OF CHASSIS FOR 6-CYLINDER, 60-HORSE-POWER CAR

cylinder of a single-acting engine, predominates to the almost complete exclusion of the "two-cycle" motor in automobile practice.

For the lighter cars the double opposed horizontal type (one cylinder on each side of the crankshaft) of motor is in the great majority. It is always of the four-stroke cycle type. In the better designs it is generally placed under the hood at the forward part of the chassis, with the main shaft parallel to the length of the car. In less frequent examples it is under the body of the car, with the main shaft transverse to the latter.

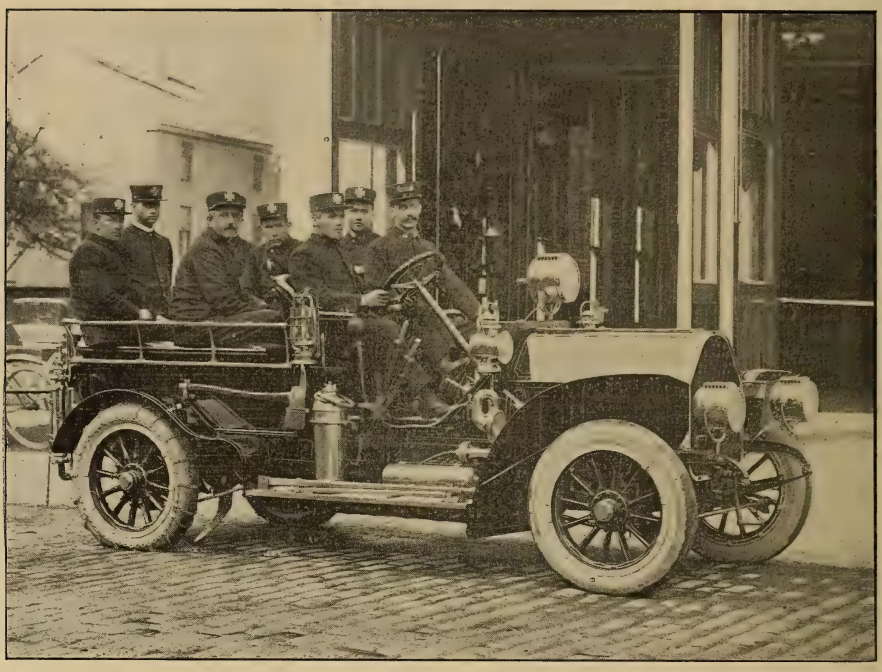
The heavier pleasure cars are almost universally equipped with four-cylinder, four-cycle vertical engines under a hood at the front, with the engine crankshaft lengthwise of the chassis. Six-cylinder engines have appeared to a limited extent. It is doubtful whether they will find much encouragement. Their more uniform torque and the consequent lightness of fly-wheel that is permissible hardly compensate for the increased cost and the loss of fuel economy. Their field will be on unusually high-powered cars. Eight and twelve cylinder engines receive attention only for racing cars and as novelties.

The mechanically operated inlet valve is gaining in favour. It is used almost exclusively on the highest grade cars. The majority of medium and low-priced ones use it also. Cost of construction and multiplication of the parts to wear out seem to have been the items that counted against its more rapid adoption. The question as to whether the mechanical or automatic valve gives the greater amount of power will probably never be settled, for there seems to be nothing appreciable in favour of either on this score. The chief count against the automatic valve is its greater liability to allow backfiring into the inlet pipe and carbureter, and to break. Backfiring comes from the weakening of the spring that closes the valve. The automatic inlet valve invariably opens downward for reasons of simplicity of design and convenience of access. When the spring weakens the valve hangs free from its seat so that, when the charge is fired, the flame passes through the partly open valve into the inlet pipe and on to the carbureter if the ignition spark is near the inlet valve, which is usually the case. The rapidly rising pressure of the burning charge drives the open valve against its seat with a



CHASSIS OF DE DIETRICH 40 HORSE-POWER MACHINE
Showing petrol tank, gear box, universal joints, chains, shock absorbers, internal expansion clutch and controlling levers

hammer-like blow that sooner or later breaks some part. The break occurs in various places. Sometimes the disk-shaped head of the valve flies into pieces that strike and break the guide through which the valve stem passes. More frequently the key or pin that passes through the end of the valve stem and holds the spring in place breaks off, or fractures the stem, and allows the valve to drop down. The result then depends on whether the broken valve can free itself from its guide and get into the combustion chamber, or remains in place and gets jammed against its seat by the lift of the exhaust valve. Broken inlet-valve guides are not unusual. When one or two nuts are used to secure the spring of an automatic inlet valve, they must be secured by a split pin or some similar device. These pins are broken by the incessant jar of their action, and the parts, falling under the valve, prevent its closing. A case is in mind where the end of the stem broke off in a much-lauded four-cylinder American car, and parts of the valve lodged under the two adjacent inlet valves so as to put them out of operation. The engine would not run,



KNOX WATERLESS CAR FOR FIRE PATROL. KNOX AUTOMOBILE COMPANY, SPRINGFIELD, MASS.

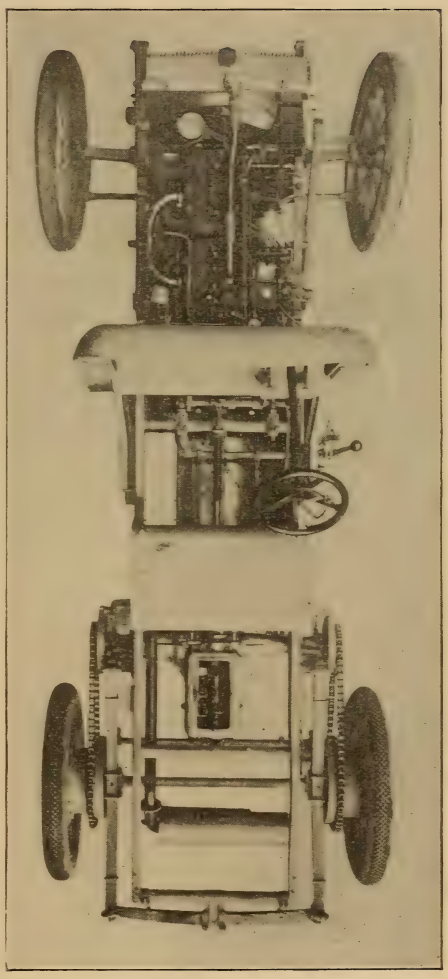
of course, on the remaining one of the four cylinders, since there could be no carburation action with the three inlet valves held open during the compression strokes of their pistons. The writer's experience has fully convinced him of the superiority of mechanically operated inlet valves. The automatic valve has in its favour, however, that when in its usual position opposite the exhaust valve, the volume of the pocket leading off from the combustion chamber can be reduced to a minimum, which is desirable.

In horizontal engines the inlet and exhaust valves are placed together either above or below the combustion chamber. The latter is kept free from any collecting of oil or water when the valves are below, but oil cannot be kept in the crank-case, and, in general, the valves are less accessible. The use of a pet-cock in the wall of the combustion chamber affords a means of draining the cylinder when the valves are above. In the vertical engine, practice is about equally divided on placing the valves on opposite sides of the cylinder, or both on one side. When both are on the same side, the pocket space leading to them can be kept smaller than when they are opposite. The engine is more economical when the pocket space is small. Combustion is completed more quickly when the pockets are small and shallow than when they are deep and narrow. The pressure on the piston comes to a maximum more quickly with small pockets, thus giving the greater economy just referred to, and also more power. There is greater stress thrown on the engine with this greater development of power. It can therefore be seen that an engine whose parts show strong enough with the valves on opposite sides of the cylinder may fail in strength if the cylinder design is changed by putting the valves side by side and making the pocket into which they open as shallow and of as small volume as possible. In connection with this, the increase of power that can be obtained by the use of

two spark plugs in different parts of a combustion chamber with deep pockets is interesting.

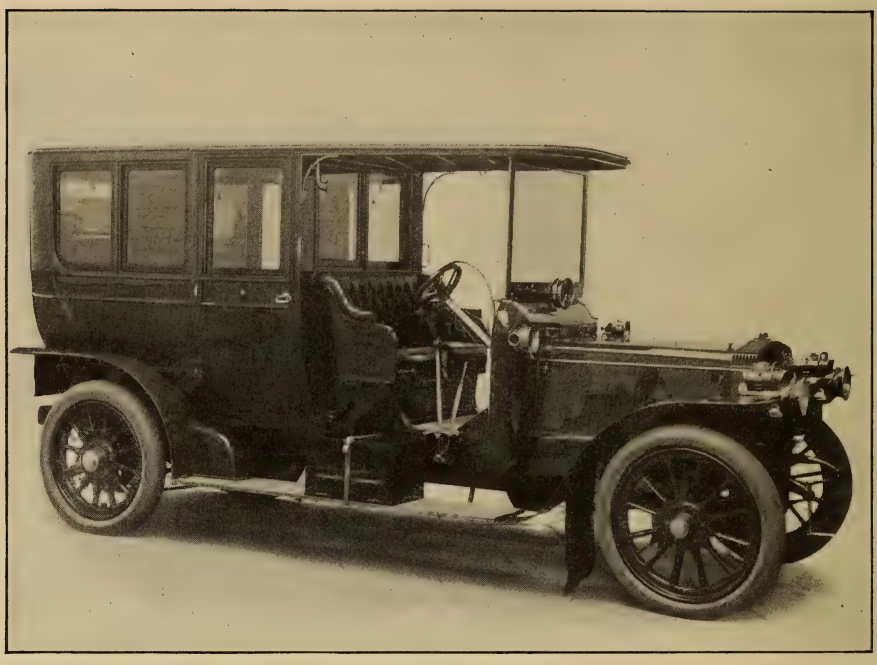
While not intending to go into the proportions of parts, a comment on the methods that are often cited as being used to determine how much a poppet valve should lift, may not be out of place. It is usually stated that "the valve should lift through a distance equal to one-quarter of its diameter, since this makes the area between the valve and its seat equal to that of the circular opening under the valve." According to this, a 2-inch valve would lift one-half an inch, which is excessive for a mechanically operated valve, and entirely out of the question for an automatic one, since it would hammer itself to pieces in a short time. The actual lift of the automatic valve should be from one-eighth of an inch to three-sixteenths. The method is at fault because no allowance is made in the calculation for the reduction of the port opening by the guide through which the valve stem passes. The guide is under the valve and in the passage in all the designs that the writer knows. The correct method of determining the valve lift is to design the port with an area of passage through the openings between the arms that support the guide from one-twelfth to one-fifteenth that of the cross section of the cylinder bore, and then give the valve such a lift that the opening under it will have the same area. This will generally keep the lift down to a reasonable amount. It can be decreased somewhat for the automatic valve, and increased slightly for the mechanical one.

The jet or spray carbureter provided with a small nozzle from which the liquid fuel is drawn by the suction of air on its way to the engine is the only type now found in use. Possible isolated exceptions may exist, but none has come under the writer's observation. The spray carbureter appears in several designs, however. The majority have a cork



PLAN OF DAIMLER 1007 CHASSIS, SHOWING SIDE CHAINS

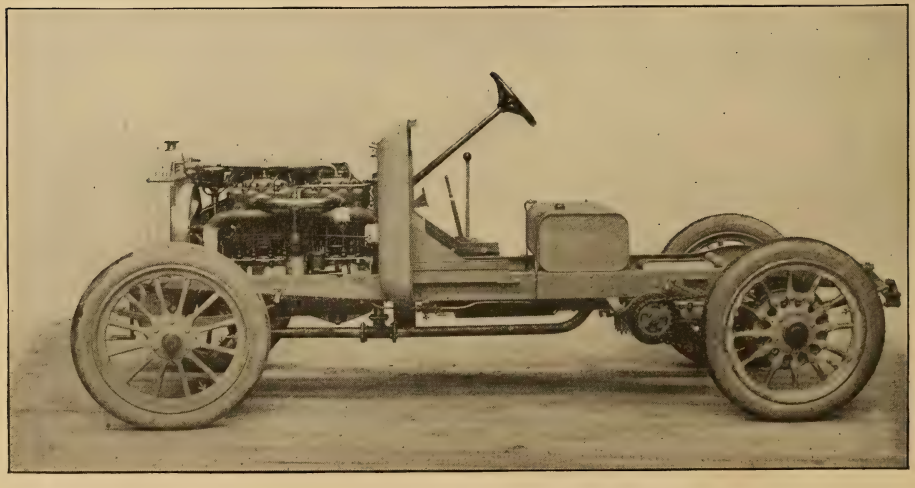
or hollow metal float in a small reservoir for regulating the level of the liquid in the nozzle from which it is drawn by the air. Other and less frequent types have no reservoirs in themselves. In such cases the flow from the nozzle is stopped, when no air is passing to the engine, by a needle valve that rests in the open end of the nozzle. When the suction of the engine draws air past the nozzle, the needle valve is lifted by the current of air striking a floating disk attached to it, or by the action of the air on a diaphragm held tight at the



DAIMLER LIMOUSINE, STRAFFORD TYPE

edge and attached to the valve stem at the center. Modifications of the last two designs appear, but are not numerous.

While the carbureter has been brought up to a fair state of perfection, still there is room for improvement. As now constructed, it supplies the engine with a mixture of as nearly the correct proportions as we are able to measure by the power developed, for the altitude and condition of the atmosphere to which it is adjusted. The setting for hot weather is not the best for cold, nor that for dry weather the best for wet, espe-



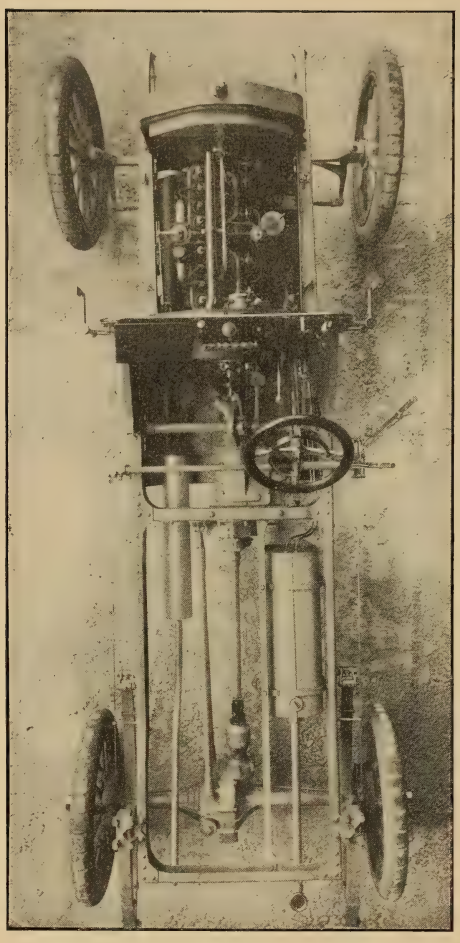
ELEVATION OF 1907 DAIMLER CHASSIS, VALVE SIDE

cially when there is great humidity. The best setting for sea level will not give near the maximum power after a mountain has been climbed. In apparent contradiction of this, there are carbureters which, once set, act satisfactorily through all sorts of weather when the altitude is not greatly varied. They are of a desirable kind. But while they keep the engine going well they do not develop its maximum power, except possibly for one condition of the air. All jet carbureters proportion the mixture by volume rather than by weight. The latter is the correct method.

The water-cooled motor is still in preponderance over the air-cooled, although the latter has done good service in several designs. Cooling by forcing air through a jacket surrounding the combustion chambers and part of the cylinders promises success. Some of the air-cooled motors can be left running while the car stands still for a considerable period, even in hot weather—in fact, for a longer time than some of the water-cooled cars with radiator fans.

In water-cooling, the water jacket surrounds from half to two-thirds of the cylinder bore, all of the combustion chamber, and the ports. The radiators have nearly all come to be of the cellular type with very thin water space and a large area of metal exposed for cooling by radiation and convection as the air is drawn through the radiator by the propeller-blade fan for keeping up the air circulation. Water circulating pumps are now mostly of the centrifugal type. Some positive in their action are still used. The gear pump, with its two spur-gears meshing closely together inside a snug-fitting case with openings for inlet and discharge, is one of the successful positive types. Other positive types, embracing about all the designs found in a complete collection of Professor Reuleaux's kinematic models, have been in use, but are disappearing.

One of the most unsatisfactory elements of the automobile mechanism is the friction clutch. The principles embodied, and in fact the designs used in most cars are, except slight refinements, as old as machinery itself. Two or more pairs of flat friction surfaces, or a single pair of conical or cylindrical surfaces are pressed together by a closure spring with enough force to prevent slipping when the motor is delivering its maximum uniform torque. In order to prevent jerks and strains in starting the car from rest when the motor is running, as is necessary with internal combustion motors, and for the same reason when shifting the change-speed gears, the force exerted by the closure spring must not be much in excess of that required for the maximum uniform torque to be transmitted. The adjustment would be a simple matter if the coefficient of friction between the rubbing (friction) surfaces would remain constant in value. But unfortunately this condition never prevails. When metal to metal friction surfaces are used, there must be ample lubrication to prevent abrasion. When the clutch is released, the lubricant enters between the surfaces. By this means perfect lubrication is obtained when the parts are first brought into engagement to transmit torque, and, in consequence, the coefficient of friction is momentarily very low. The closure force must be high enough to squeeze the lubricant out from between the surfaces in a short time, however, and force them into contact. As soon as this metallic contact is established the frictional resistance increases many fold, and the result is a heavy strain on the power transmission elements, as is shown by the sudden speeding up of the car and checking of the motor, but infrequently accompanied by spinning of the road wheels. In designs where the inertia of the fly-wheel is transmitted through the crank-shaft to the transmission mechanism, the crank-shaft is also subject to heavy



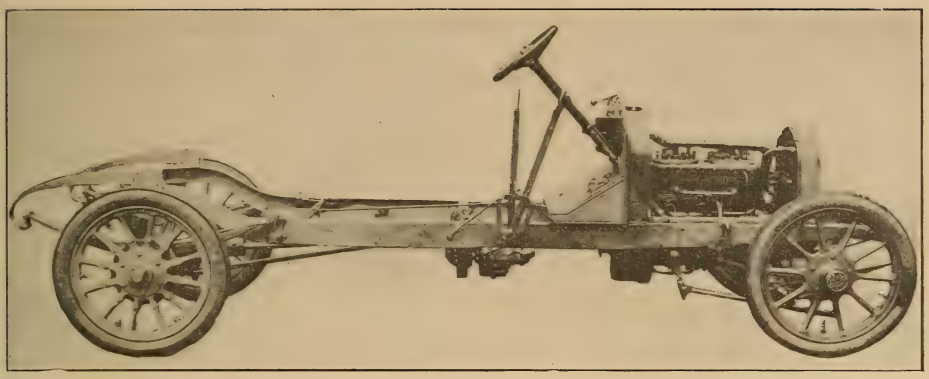
CHASSIS OF SIDDELEY CAR. THE WOLSELEY TOOL AND MOTOR CAR CO., LTD.

stresses. If the friction surfaces become unduly heated, or if abrasion occurs, then the friction becomes enormously higher than under normal conditions with corresponding unsatisfactory operation. It is impossible to adjust the closure spring to meet all these conditions. On a level road the manual manipulation of the clutch can be such in many cars, especially in heavy ones, as to prevent much visible evidence of unsatisfactory action. But in hill climbing over bad roads it is generally very evident.

Leather to metal friction surfaces have a fairly constant frictional resistance so long as the leather is new and free from oil and grease. But in time the leather becomes glazed or oily. In either case the coefficient of friction is lowered in general and the closure spring must be set harder to provide the requisite torque. Under these conditions, however, the surfaces will at times suddenly grip or seize each other with a force far in excess of the ordinary, with the usual stresses and jerks. This seizure generally occurs when the surfaces are cool, as when the car has been idle for some time, or running without release or slip of the clutch.

A clutch that will make it impossible to transmit excessive torque is a desideratum. Such a clutch, that promises much in the mechanical field, has recently been devised. In it the power is transmitted through springs of simple form whose deflection by the torque regulates the pressure between the friction surfaces so that, when a predetermined torque is reached, the friction surfaces are caused to slip over each other while still exerting the maximum turning effort to which the clutch is set. The effects of a variable coefficient of friction upon the torque transmitted, as cited above, are eliminated. The limit of torque is fixed by the resistance of the springs, which is a constant value for any given setting of the clutch. The principle of its operation is new, and applicable to both conical and multi-disc types.

In change-speed transmission gears it is a deplorable fact that the type which is the most quiet, durable, efficient and compact—the sliding gear transmission—is also the most awkward and liable to breakage and minor injuries while changing from one speed to another. At the best, heavy strains are brought upon it while making the change. With only one or two exceptions, sliding gears are used on heavy cars. Planetary gear transmissions, with their commendable ease of shifting from one speed



CHASSIS OF 20 HORSE-POWER MORS MACHINE, WITH LIVE AXLE

to another, are used on several of the lighter cars as well as on some of the heavier ones with four-cylinder engines.

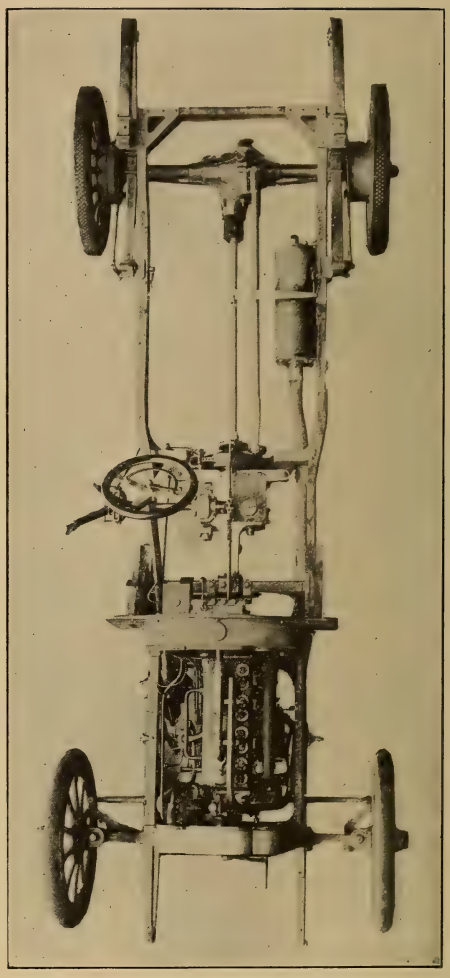
The side chain drive for the rear road wheels with their solid axle is still struggling for supremacy with the propeller shaft axle drive in which the propeller shaft transmits power from the engine to the divided rear axle. The differential gears for allowing the rear wheel to revolve at different speeds when rounding a curve are connected to the two parts of the rear live axle when the propeller shaft drive is used; in the side

MORS CAR OF 45 HORSE-POWER MORS, ENGLAND

chain drive they are attached to the two parts of the divided jackshaft that passes across through the rear end of the change-speed gear box and carries a sprocket wheel on each outer end. The two systems have about equal favour for heavy pleasure cars, but a single chain running from the engine under the body of the car back to a sprocket wheel rigidly attached to the casing of the differential gears on the divided live rear axle still finds considerable favour. Propeller shaft drives are becoming more general for light cars, and appear to be gaining ground on heavy ones. The side chain drive has the advantage of a solid rear axle with its corresponding lightness and rigidity, a flexible chain connection between the jolting road wheels and the more steady frame of the chassis, and a compact nest of machinery fairly high above the road, and consequently as free from dust and mud as possible. Its only disadvantage, so far as the transmission of power is concerned, is in the use of a chain exposed to dust, mud, water, flying stones and sticks, and noisy in the extreme. It is never free from grit after going into use, and although its life is wonderfully long for the abuse it receives, breaks are not unusual even when it is quite new. They are sure to come if it is run too slack, or after the pitch has become so elongated as to allow it to climb on the tops of the sprocket-wheel teeth and break itself or the wheel, or both. Side chains are the weak links in their system of power transmission.

A single chain running to the middle of a live rear axle is far less exposed to foreign matter than those on the sides. It can be amply lubricated without deluging the car. On the whole, it gives good service.

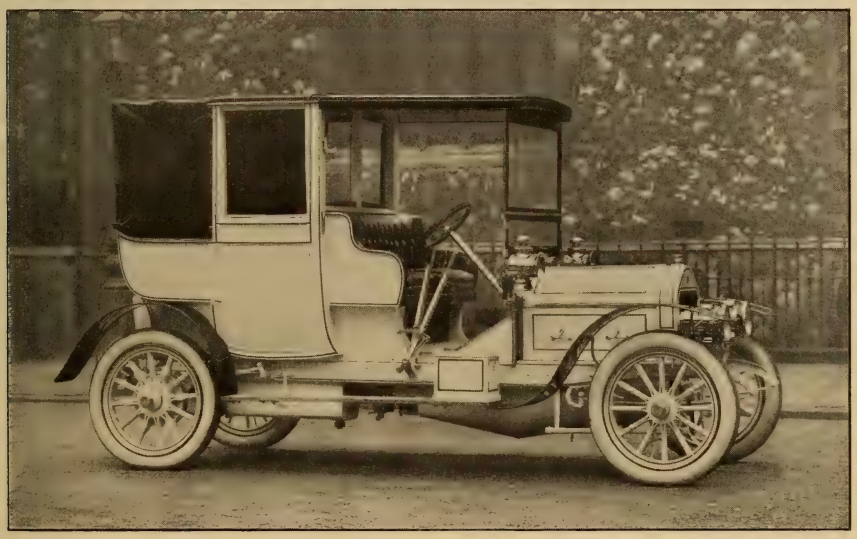
The chief advantage of the propeller shaft drive is that it eliminates the side chains. This is an advantage well worth considering. It gives quiet running and is not subject to frequent breaks. The divided rear axle is heavier than the solid one, but it can be made strong and durable without becoming clumsy. The road wheels can be carried either on the ends of the live half-axles that transmit power to them, or they can be run on the dead casing of the rear axle and receive power from floating live half-axles, which are thus relieved of supporting the car, and can be made of smaller diameter in consequence of such relief. Probably the greatest disadvantage of the propeller shaft is the necessity of using flexible joints in it to allow for the action of the springs between the axle and the



PLAN OF MORS CHASSIS. THE TWO BENDS IN THE FRAME PERMIT A DEEP LOCK

frame of the chassis. These joints are generally some form of the Hooke's coupling. They must be thoroughly protected from dust and grit by some covering, such as a leather, canvas or oilcloth boot, securely strapped and laced in place. A metal casing in two hemispherical parts is used on some machines. The covering should be filled with thin grease or very heavy oil. An unprotected joint in a rotating shaft will soon lose all its lubricant and then cut

The spur-gear differential has double the number of small intermediate gears between the two large ones on the inner ends of the half axles that are found in the bevel gear type. Two small spur gears are substituted for each of the small bevel gears. Since they are all spur gears with their axles parallel, there is no end thrust induced. Spur-gear differentials using all spur gears are larger in diameter than bevel differentials of the same strength. But by



SIDDELEY LANDAULETTE, 30 HORSE-POWER. SIMILAR TO ONE SUPPLIED TO H. M. THE QUEEN. THE WOLSELEY TOOL AND MOTOR CO., LTD.

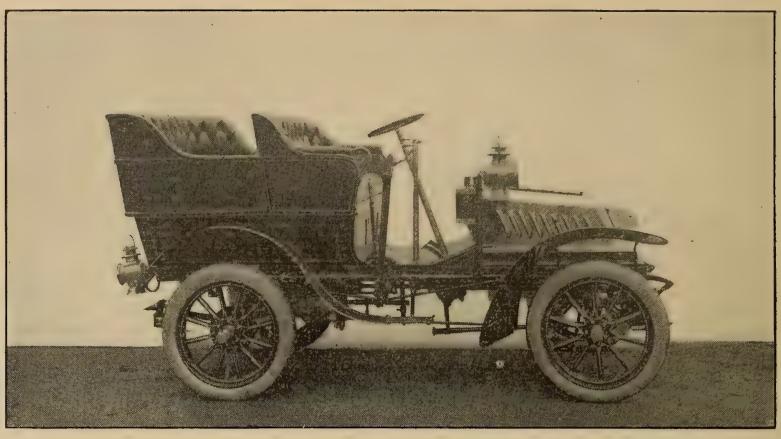
itself out with extreme rapidity. The propeller shaft does not interfere with the free action of the springs and the easy riding of the car.

Differential gears are used in both the bevel and spur gear types. The bevel-gear differential has a large gear on the inner end of each of the live half axles, and two to four small gears between them. The axes of the latter are perpendicular to the axle. While the bevel gear construction is the simpler, it has the disadvantage of end thrust on the live axles and the small intermediate gears. The end thrust causes somewhat rapid wear and the consequent incorrect meshing of the gears with each other.

using annular gears on the half axles, the diameter can be kept as small as that of the bevel one.

Ball bearings are used to a considerable extent on the crankshafts of the engines. The ball and plain journal types cover the types adopted. The crank-pin and wrist-pin bearings are, with very few exceptions, of the plain cylindrical form. Tests of ball bearings do not show it advisable to adopt them at the ends of the connecting rod.

The transmission gear shafts are, like the crankshaft, supported on either ball or journal bearings. The ball bearing is less used here than in the engine, although adopted to a considerable extent. Road wheels and



DE DION-BOUTON CAR WITH TONNEAU CARRIAGE BODY, 1907. 8 HORSE-POWER
DE DION-BOUTON, LTD., LONDON

live axles are equipped with ball or roller bearings. Cylindrical rollers are generally found on the live axles. The elastic roller made by winding a ribbon of steel, rectangular in cross section, to form a helix of uniform diameter is the predominant type. It is the most suitable for this use because it can be used in the hollow axle without machining the hole, and adjusts itself to irregularities of wear readily. Solid rollers of the full length of the bearing will break sooner or later. Ball bearings are infrequently used on the live axle. The elastic roller bearing has shown itself most suitable for this purpose.

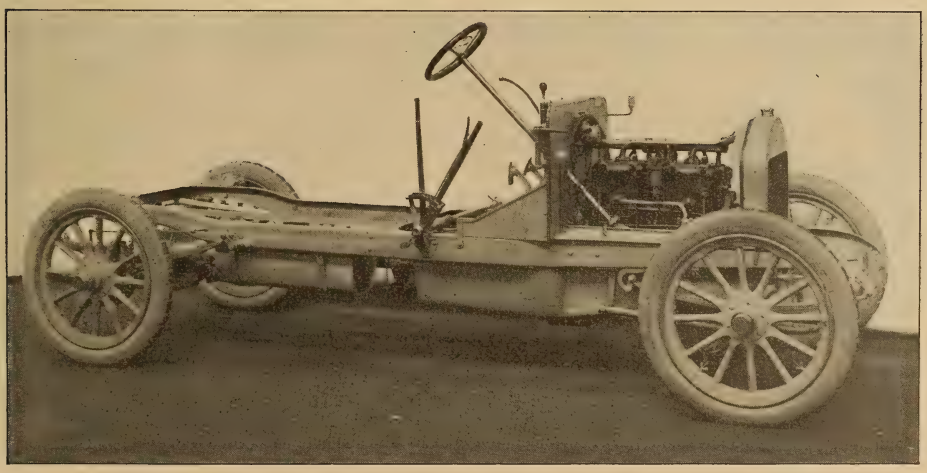
The bearings used in the hubs of wheels are either those with balls or conical rollers. Cup-and-cone ball bearings are the ones used. The balls and races stand up surprisingly well under the heavy loads when made of high-grade steel properly tempered and carefully finished on the rolling surfaces. Anything but the best quality of steel races fails on the heavy cars. The ability of ball bearings to carry such heavy loads is accounted for by absence of shock secured by the use of pneumatic tires. The conical roller bearings are used in pairs in the wheel hubs with the small ends of the rollers toward each other. Both the concave and convex surfaces of the races are conical, to conform with the taper of the rollers. A strong cage is used to retain the rollers in exact position. Longer bearing surfaces are obtained with roller bearings than with balls. Ball and roller bearings in road wheel hubs are frequently destroyed by setting them too tight when putting the wheel in place. The untrained chauffeur thinks they should be tightened till the wheel begins to turn hard, in the same manner that a plain spindle carriage wheel with leather or wood-fibre end washers does when adjusted so as to give no rattle from end play. Such adjustment flakes and splits the balls and scores the race, if it escapes fracture.

Practically all pleasure and passenger automobiles are steered by heading the front road wheels in the direction to be traveled. Some public conveyances steer by swiveled rear wheels and drive by the front wheels. A car can be handled best by steering with the front wheels and driving with the rear ones, even on good, dry roads. On slippery roads the advantages of front wheel steering are vastly greater, especially in the absence of anti-skid devices on the driving wheels. When driving power is transmitted to a wheel on a slippery road the wheel will always creep around with a slight sliding

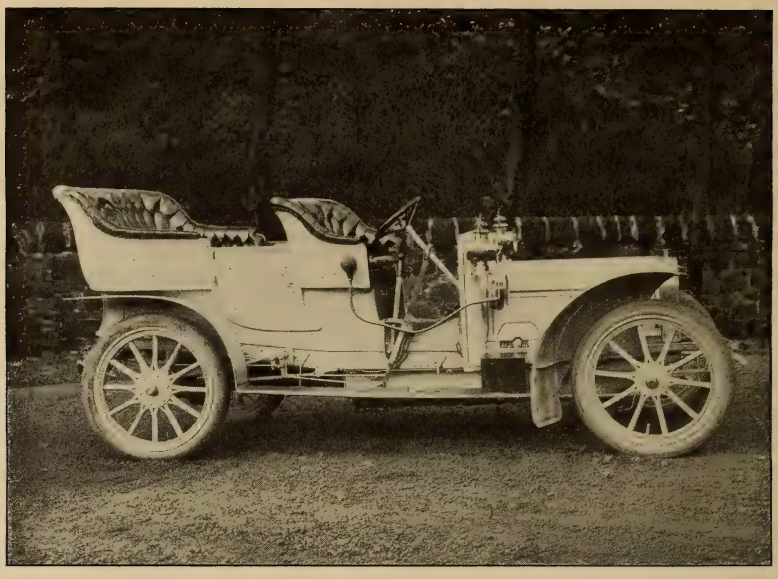
motion on the road surface, even if it does not spin. Even the very slightest creeping or slight slip allows it to move sidewise far more easily than if it were only rolled along like the steering wheels. When steering by the front wheels and driving with the rear ones, the car can be kept headed somewhere in the direction to be traveled, and generally made to follow the road, provided the speed is not high. But with rear-wheel steering and forward-wheel driving the car is apt to head in any direction, even when starting from rest, and, under such conditions, cannot be steered at all. Steering and also driving with the front wheels has not been tried fully enough with pneumatic tires to give conclusive results. Electric automobiles have been in regular use to a small extent for about a year, however, in which each front wheel is driven by its own motor, and the same wheels deflected, also by the motors, for turning curves. All indications are that this type cannot be so well steered, for reasons similar to those already mentioned, and entirely apart from the method of deflecting and driving the wheels.

The usual practice is to place the pivot on which the steering knuckle that carries the road wheel swivels as near the inner end of the hub as possible. The forces acting on the swivel are thus kept down in value and held as near vertical as possible. In a few designs of the earlier electric vehicles, the hub is hollowed and the axis of the vertical swivel pin lies in the plane of the center line of the tire. This frees the swivel from side stresses to the utmost and allows it to turn with the greatest freedom. The design is very unusual.

Much care has been taken to provide means of taking up lost motion in some parts of the steering gear. It is not unusual to find such provision where the wear is comparatively slight, while nothing has been done in some of the places where it is large and rapid. The fault is generally due to lack of knowledge of what will be the relative rate of wear in the different rubbing surfaces. Thus, in one design, there is an elaborate arrangement for adjusting the depth of the mesh of the worm and worm-wheel at the lower end of the steering column, but there is nothing whatever to adjust for the wear of the worm-wheel shaft in its bearings. To be sure, the rubbing between the worm and its wheel is much more extensive and under heavier unit pressure than that of the worm-wheel journal in its bearings,



SIDDELEY CHASSIS. WOLSELEY MOTOR CAR CO., LTD.



ARROL-JOHNSTON CAR, 24-30 HORSE-POWER. THE NEW ARROL-JOHNSTON CO., LTD., UNDERWOOD, PAISLEY

and it may therefore naturally be assumed that the wear at the journal will be inappreciable. But, on account of the exposure of the end of the worm-wheel shaft to dust and mud, it cuts away rapidly in proportion to its slight motion, while the teeth of the worm and the wheel, carefully made and packed in grease so that no foreign matter can encroach, shows nothing more than a slight brightening of the rubbing surfaces after the wear at the journal of the wheel has become so great as to necessitate new parts. Such instances are numerous.

The worm and worm-wheel are extensively used for steering. A smaller proportion of cars have a screw thread and nut at the lower end of the live part of the steering column. The nut moves up and down as the steering hand-wheel is turned. Sometimes there is both a right-hand and a left-hand nut at the lower end of the live steering column. In such a design the nut for the upper thread is stationary and the column moves up and down through it as the hand-wheel turns, while the lower nut travels over the thread at the lower end of the column. The speed of travel of the lower nut is twice as rapid as if the column rotated in a plain journal bearing with collars. The handwheel moves up or down as it rotates. In another design a bevel gear at the lower end of the live steering column transmits motion to a segmental bevel gear of larger radius, whose axis is at right angles to that of the column. In all the above devices, the part that lies under the floor of the car and is moved by turning the steering wheel is connected to an arm which in turn connects by means of a reach-rod to another bell-crank arm on one of the steering knuckles of the road wheels. Numerous other devices, generally involving a screw and nut, are applied to a smaller extent. But in very light cars an extremely simple steering gear finds much application. It consists of merely a bell-crank at the lower end of the steering column, connected to the steering knuckle by the reach-rod. Ball-and-socket joints are used at the connections.

Brakes are powerful enough in all the later cars and in most of the earlier ones, but they do not have sufficient wearing surface. They an-

swer for city use and short tours through a comparatively level country, but when mountainous roads are traversed they are soon worn out. Water cooling is necessary on long descents. The primitive method of flowing water on the surface of the drum or shoe is the only one yet adopted. The use of the engine as a brake affords relief. The engine brakes best when the petcocks leading to the combustion chamber are open. Equalizer bars, or cables for the same purpose, are used on the hub brakes to a limited but growing extent. It should be remembered in connection with their use that, even if the equalizer is perfect, the brakes will offer the same resistance to the rotation of the road wheels only when the coefficient of friction is the same in both brakes. When the differential lies between the brake and the road wheels, the brake resistance to turning is the same for both wheels. This appears very markedly when one wheel is running on a wet, slippery asphalt pavement and the other is on a dry surface, the condition often met after a street sprinkler has passed. The braking effort is measured by the wheel on the slippery surface. It skids and rotates backward if the brake is applied hard. Hub brakes will stop the car more quickly under such conditions, but must be applied carefully so as not to swing the rear of the car around and bring both rear wheels on the slippery surface. Both internal and external shoes are found on the same drum attached to the rear wheels on some cars. This is entirely satisfactory for fairly level country and the city; but for touring over steep and long grades it is not the best plan. The drum and band should be exposed to the air as much as possible for cooling when put to such service. With a shoe inside and another outside, there is little opportunity for the air to reach the drum. If the drum breaks, both the internal and external brake systems are put out of commission. The fracture of the drum by a too powerful application of the brake is not unusual with the beginner who has not been trained in the use of machinery.

The prevailing forms of chassis frames are the rectangular type with sub-frame for supporting the engine and gear box of the change-speed gears and the type with contracted front, whose sides, brought nearer together for a few feet at the front, support the engine directly. Those with steel channels riveted together, with braces at the corners, are in the large majority. A few are reinforced with wood. One frame is made up of tubes whose cross section is a rectangle with rounded corners; the tubes are filled with wood to reinforce them. Only a few examples of wooden frames are found.

With a few exceptions, the frames are supported by four springs that connect them directly to the axles. This gives but slight flexibility for conforming to inequalities of the road. The stresses that are produced in the frame, body and springs when a wheel passes over a high obstruction, or drops into a hole, are excessive. The broken springs, strained frames and steering gears that came out of a recent road test are witnesses of this. The above plan of four-point suspension gives a most suitable car for good roads, but one that will not endure the stresses caused by running over bad ones. Three-point suspension has been successfully applied to several cars, most of them of light weight.

The majority of automobiles are, like the English and continental locomotives, built for good roads. Such automobiles are no more suited to the average American country road than the English locomotive is to the wavy and uneven track of minor railways in the United States and in the colonies. They both are bound to run on three wheels on the bad roads. American locomotives are built for uneven tracks and sharp curves. They present a most excellent example for the automobile.

PRODUCER-GAS COMPOSITION AND ITS INFLUENCE ON THE PERFORMANCE OF SUCTION-PRODUCER PLANTS

By Godfrey M. S. Tait

The suction gas producer has found many applications during the few years in which it has been before the public, and it is now well established as a convenient and economical system for many purposes. One of the questions under discussion in connection with its operation relates to the most desirable composition of gas for best operation of the gas engine, and this feature in suction-producer operation forms the special subject treated by Mr. Tait. The advantages and disadvantages of hydrogen in power gas have been mentioned in connection with large gas engines in other articles in this issue, and it is by experiments such as Mr. Tait has conducted that the question may well be investigated in smaller installations.—THE EDITOR.

DURING the past four years suction producers have been gradually appearing upon the American market, and quite a large number of installations are now in operation, with more or less success, in this vicinity.

However, unfortunately the defects noticeable in the older type of pressure producers, such as variation in the quality of gas, inability to clean the fire without interfering with the manufacture of gas, necessity for having a spare unit, etc., are all more noticeable with the suction type than with the former type of pressure producers, with which a large gas holder was usually employed for the purpose of steadying up the output of the installation and allowing the gas to assume a more average condition before reaching the engine.

Almost without exception, some trouble has been experienced in every producer plant used for the operation of gas engines from irregularities in the operation of said engines, due to changes in the gas beyond the control of the operator, and it was with a view of ascertaining what these changes were, and to find, if possible, a remedy therefor, that the writer made a series of experiments on the subject, and with the following results:

In operating internal-combustion engines on a complex fuel, such as producer gas as usually manufactured, analysis of which I give herewith:

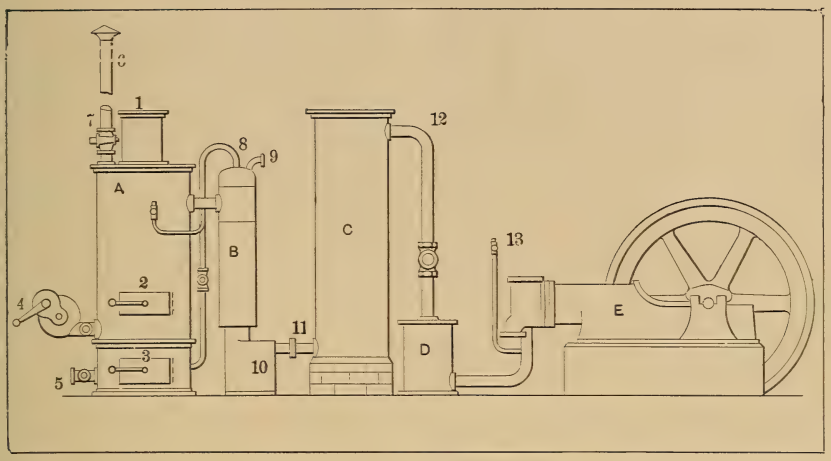
	Per Cent.
1. Carbonic acid (CO_2)	5.8
2. Oxygen (O_2)	1.3
3. Carbonic oxide (CO)	19.8
4. Hydrogen (H_2)	15.1
5. Marsh gas (CH_4)	1.3
6. Nitrogen (N)	56.7
Total	100.0

7. B. T. U. per cubic fot of gas by calorimeter (high value) . . 136,

it is noticeable that the heating value is composed of elements of widely different character, such as hydrogen and carbon monoxide.

Following the matter up further, I made the discovery that the thermal or calorific value of the gas employed does not necessarily form a true index of the power value of a gas for engine work, and this was proven in the following manner:

An internal combustion engine of the three-cylinder vertical type, rated at 100 H. P. on producer gas containing 13.3 hydrogen and 23.8 carbon monoxide (plus a small percentage of marsh gas) and having a total calorific value, as determined by the calorimeter, of 138 British thermal units per cubic foot, was



GENERAL ARRANGEMENT OF SUCTION GAS PRODUCER WITH STEAM SUPPLY. A, PRODUCER. B, STEAM GENERATOR. C, D, SCRUBBERS. E, GAS ENGINE

Vapour of water from the generator is delivered below the grate, giving a semi-water gas.

found to develop a maximum under the very best conditions of 106 H. P. By the very best of conditions, I mean with the fuel in the producer free from clinkers and of sufficient gasifying depth to create a temperature to give the best results.

After obtaining this horse-power, I removed the apparatus for feeding steam beneath the bed of the producer, with a view to eliminating the hydrogen constituent in the gas. The gas under this condition showed 24.3 carbon monoxide, which constituted practically the sole combustible matter in the gas (with the exception of the small percentage of marsh gas above alluded to), this gas having a calorific value of 91 British thermal units per cubic foot. With this gas and the same engine, I developed 114 H. P. with ease, and was enabled to carry a load until the fire in the producer became overheated.

I then employed the exhaust from the engine under the fuel bed in the producer for the purpose of diluting the incoming air and reducing the temperature of the fuel bed. (In doing this, I was utilizing a patented process for flame and combustion temperature regulation now very largely known in several industrial fields.)

Going a step further, I increased the compression of the engine to 200 pounds, on the assumption that, with no hydrogen in the gas, the tendency to pre-ignite would be absent, and the attendent advantages might as well be derived.

With this arrangement the producer operated with entire satisfaction twenty-four hours per day, with full or varying loads, while the engine, on the other hand, gave no trouble whatever, and there was an entire absence of pre-ignition, backfiring, etc., troubles which had been noticeable before. In addition to these advantages, the engine developed a maximum of 126 H. P., and would carry 110 H. P. with the greatest ease continuously, while, due to the high compression and accurate ignition produced when using a gas containing only one active constituent, the efficiency of the engine increased 15 per cent. above its former rating; that is to say, the total efficiency of the engine was 26 per cent. under these latter conditions.

When it is considered that the gas used in the second instance contained 47 British thermal units less

per cubic foot than the gas used in the former test, and that in the face of this the efficiency of the engine and the horse-power capacity both increased to a marked extent, some idea of the importance of this deduction will be appreciated.

I found that this increase in horse-power efficiency is due primarily to the fact that mixtures of gases whose components burn at different rates or velocities, such, for instance, as the usual mixture of carbon monoxide and hydrogen, usually known as producer gas, are not well suited for engine practice, and do not represent, by their total heating value, the amount of work obtainable from them in a gas engine cylinder, for ignition is either too early for the hydrogen, which is a gas of extremely combustible character, or else ignition occurs too late for the less combustible or slower burning carbon monoxide. Either state of affairs causes a loss of power, pre-ignition, back-firing or late ignitions.

At the present time the chief difficulty in operating internal combustion engines with producer gas arises from the great variation in quality of the combustibles contained therein, which necessitates the closest attention on the part of the operator and the frequent adjustment of the air and gas valves on the engine, and it was while working out the cause of these variations and the remedy therefor that I made the above-mentioned discovery, that the thermal value of gas does not indicate its power value in an engine when it contains more than one combustible element, and that, owing to changes in the temperature of the fuel bed in the producer supplying the engine with gas, affected in turn by variations in the load on the engine, it is impossible to produce a gas containing fixed proportions of hydrogen and carbon monoxide; for, on the one hand, when the plant is running under a low load, the fuel bed, being cooler, will allow part of the steam to pass up through the fire without dissociation, merely superheating same, and this superheating of necessity carying off heat units which are in turn lost in the scrubber water without having performed any useful work.

Owing to this varying quality of the gas, the time of ignition is rarely accurate, and this state of affairs gives rise on the one hand to pre-ignitions and on the other hand to back-firing.

It, therefore, would seem that in order to secure a constant, regular and steady run from the gas engine, only one combustible element should be present in the gas used. If the presence of other combustible matter, such, for example, as marsh gas, is unavoidable, the quantity should be restricted to the least possible amount.

When producer gas is made, as has already been mentioned, by the passage through a fuel bed of a draught current containing air alone, provided that the fuel used consists largely of carbon, such as anthracite coal, charcoal or coke, the gas as produced contains only one combustible, namely, carbon monoxide, the balance of the gas being inert nitrogen.

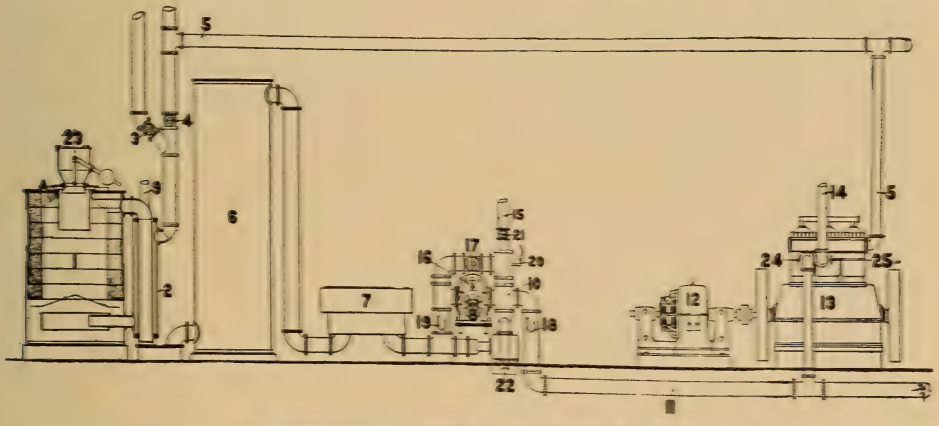
Provided all the oxygen admitted is reduced to carbon monoxide, the finished gas should contain, theoretically, 34.7 of this monoxide. Each per centum of carbon dioxide present reduced to carbon monoxide being 2 per cent., inasmuch as one molecule of carbon dioxide contains two atoms of oxygen, while carbon monoxide contains one atom, and consequently one-half of the oxygen of carbon dioxide. In other words, one volume of carbon dioxide on reduction by carbon will produce two volumes of carbon monoxide.

For the prevention of clinkering of the producer and for the purpose of so-called enriching of the gas, steam has hitherto been used, mixed with air, as the ideal blast for producers, it being claimed that the steam in the blast supplied a cer-

tain amount of oxygen for the oxygenation of carbon, without, however, introducing nitrogen at the same time.

Hydrogen is produced in direct proportion to the amount of steam decomposed. It has been supposed, therefore, that hydrogen, in raising the heating value of the gas, increased its power value in an engine, and as for this reason, the greater the amount of steam employed, other conditions being equal, the higher the percentage of hydrogen; thus it was assumed that a greater value from the engine standpoint was obtained in the gas. However, as above mentioned, it will be seen that the assumption that the greater the proportion of hydrogen, the greater will be the power developed by each cubic foot of gas in a gas engine cylinder, is erroneous. It is true that a gas producer, under a pure air blast, will generally give a product having a lower calorific value per cubic foot than those operated with steam and air in conjunction; but it is not true that such a gas is a better agent for the development of power than a hydrogen containing gas. On the contrary, it is a far superior gas for power development in every practical respect, even though the gas so made should have one-third less thermal value than that of ordinary producer gas; the very fact that the former contains only one active combustible, with a fixed ignition point and adaptable to high compression, gives it the property, as already mentioned, of developing more actual power in an engine for reasons above mentioned.

A recent installation of a plant comprising the above theoretical points may be of interest to our readers, and herewith will be seen a diagrammatical illustration of the same. By referring to this drawing, 1 is a producer shown in vertical section and comprising the usual type of suction producer, with the exception that there is no evaporator or other steam-forming apparatus in conjunction with it.



SUCTION-PRODUCER PLANT WITHOUT STEAM SUPPLY

The fuel is dumped in through hopper 23, and the gas, formed at night when the fire is banked, passes off through pipe 9, as per the usual practice. This plant, in addition to the above-mentioned points, also embodies a special exhauster device gotten up by the writer and which is also shown.

For starting up this plant in the morning, the attendant starts motor 8, which in turn rotates exhauster 16; valve 17, however, in by-pass pipe 17, is wide open, so that no sucking action occurs. The operator then opens valve 21 in waste pipe 15.

At 22 will be seen a by-pass water seal, which is so arranged that any

pressure in pipe 10 over a predetermined amount will break the seal in water-seal pot 22 and short-circuit the exhauster (to use an electrical term).

After the exhauster 16 has been put in motion by means of the gas engine or small motor, the vent pipe 9 at the producer is closed, and the pipe connection between producer 1 and scrubber 6 is opened. Then by slowly closing valve 17, a gentle suction will be formed up through the fuel bed in producer 1, through downtake of producer and up through scrubber 6, purifier 7 and through exhauster 16, and thence out through vent pipe 15.

The strength of this induced draught may be varied at will by partially opening or closing valve 17, for, as will be noted, when valve 17 is closed, all the gas discharged by exhauster 16 will pass up and out through pipe 15, there being no other outlet available except through water seal 22.

At 19 and 18 will be seen two U-tube water gauges for indicating the respective suction and pressure on the gas line; 19 should show about 2 inches suction and 18 should indicate from $1\frac{1}{2}$ inches to 2 inches pressure.

After the exhauster has been running a few minutes, the attendant should try to ignite the gas issuing from burner 20, and as soon as he is able to obtain a steady blue flame, the engine 13 may be started, after which waste pipe 15 should be closed. The exhaust of the engine, as will be seen, passes up through pipe 5, where part of it goes to the atmosphere and part descends through valve 4, combining with the air supply through valve 3 and flowing down through pre-heated jacket (2) and tube under the bed of the producer, it being obvious that by regulating valves 3 and 4 any desired mixture of air and exhaust gases may be obtained.

The gas main 11 supplies gas to two or more engines, as desired, and as shown in this illustration; 14 is the air inlet pipe to engine, and 24 and 25 are, respectively, the gas and air-mixing valves. At 12 will be seen the direct-connected generator as installed with each engine and supplying direct current at 240 volts, both generators working in parallel with perfect distribution of load.

A plant of this character, and of which this cut is a diagrammatic view, was recently installed as the sole source of power for the John Thompson Press Company, Long Island City, the equipment consisting of one suction producer and two vertical three-cylinder engines of 125 H. P. and 50 H. P., respectively.

The service for this plant is exacting, inasmuch as it operates twenty-four hours per day, six days per week, on from maximum to low load, frequently carrying a considerable overload without any trouble whatever from clinkering of the fuel, and with absolutely no variations in the quality of the gas.

It would seem, from the writer's experience, that this simple change in the lay-out of a producer plant has brought this character of installation up to a par with steam plants in point of reliability, while at the same time, so far from losing any of the acknowledged economies of producer gas operated gas engines, the efficiencies are considerably increased, and the writer feels that, as Mr. George H. Barrus said, after inspecting another installation of this character, "No steam plant could have operated with more complete regularity, and no more care was exercised in the handling than that given by firemen and engineers in the firing of a good steam plant."

It is interesting to note that the engines employed under these conditions operate under compression upward of 200 pounds with entire freedom from pre-ignitions, proving conclusively that in whatever way hydrogen may or may not affect the pre-ignitions, they are not present in its absence.

RECENT APPLICATIONS OF GAS POWER

By J. R. Bibbins

IT is often instructive, in connection with work along lines characterized by extremely rapid development, such as gas power engineering, to assume the retrospective frame of mind. The following notes merely attempt to bring into prominence some of the interesting features that have accompanied developments in the application of the internal-combustion principle.

First, a résume of work in the early days shows that a very large number of medium-sized plants have been installed. Taking the output of one builder alone—the Westinghouse Machine Company—records show that at the close of the year 1906, 588 plants had been installed, aggregating 97,122 brake-horse-power, or 1,652 brake-horse-power per average plant. With the important work done during the present year, especially in large-sized engines, the average per plant at the end of 1907 will be materially increased. This summary represents less than ten years' active operation in the gas power field, and, of course, includes small plants in the early days, as well as the large plants of recent years.

If it were possible to present here in detail the different industries to which gas power has been applied, the result would show an extraordinary array, covering almost every modern industry using power, from the retail coffee house to the high-speed interurban railway or the blast furnace power plant. The following figures are, however, interesting in so far as grouping of industries serves to indicate the trend of practice. Neglecting all plants below 100 horse-power capacity, an analysis of the data above presented shows:—

11,000 H. P. installed in plants ranging from 100 to 200 brake-horse-power.
21,000 H. P. installed in plants ranging from 200 to 500 brake-horse-power.
20,000 H. P. installed in plants ranging from 500 to 1,000 brake-horse-power.
30,000 H. P. installed in plants ranging from 1,000 to 5,000 brake-horse-power.

This totals 196 plants installed above 100 brake-horse-power, aggregating 86,266 brake-horse-power. That the small plant does by no means preponderate, is shown by the fact that only 17 per cent. of the total is represented by those below 100 brake-horse-power capacity. Of the above total, electric lighting and power stations represent 23.8 per cent. of the power installed; electric traction, 4 per cent.; manufacturing and general industries, 58 per cent.; private and miscellaneous, 14.5 per cent. In this summary electric traction has made relatively small progress, but recent developments along this line, as later noted, will very materially alter the situation a year or two hence.

Outside of the application of gas engines to the familiar service in electrical lighting and traction stations, isolated plants and factory drive, involving continuous service, may be mentioned several applications in which the adaptability of gas engines to intermittent working is utilized to the best advantage. In the gas engine plant the standby losses are nil, except where producers are used, and even then but a fraction of the losses in a corresponding steam plant. This fact has favoured gas power where steam power would be quite out of the question. An extremely prominent example is the high-pressure fire pumping station now being adopted

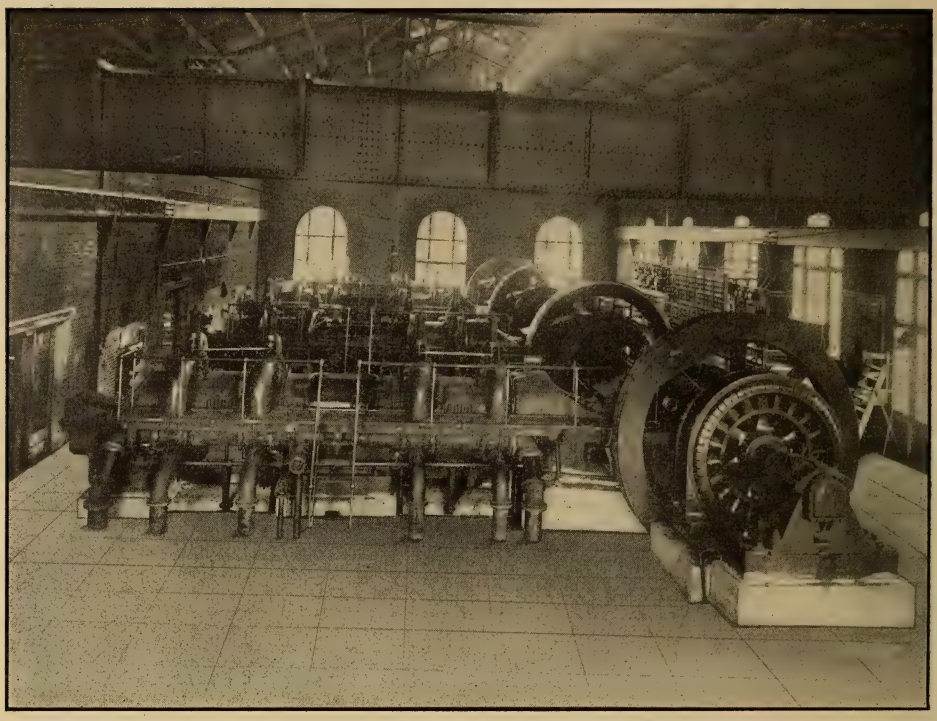


FIG. 1.—GAS-POWER PLANT, ATLANTIC REFINING CO., POINT BREEZE, PHILADELPHIA. OPERATING WITH "FIRST DISTILLATE OIL GAS." WESTINGHOUSE MACHINE CO., PITTSBURG

in large cities for the protection of congested districts, as already in operation in Philadelphia and under way in New York City. In the general scheme of canalization projected by the United States government on the Ohio River near Pittsburg, the machinery for the operation of the locks at various stages is run by gas engines. Here this form of prime mover is at its best advantage—always ready for service without stand-by losses.

A rather novel application is being made in the West, in which gas engine-driven centrifugal pumps are used for hydraulic excavation. Owing to the existence of a high ridge between the Kaw River and the Missouri, Kansas City & Texas Terminal Company's property, about three miles from the river bank, it became necessary to remove this obstruction. The hydraulic equipment consists of a 12-inch pipe running from the river to the crest and three pumping plants in series—one on a flatboat on the river, another at the river bank, and a third, a 175 horse-power gas power pump, part way up the slope. With this plant, it is estimated that 500,000 cubic feet of sand could be removed, and the installation of a gas driven pump would result in an estimated gain of 50 per cent. in the capacity of the plant and rate of deposit in the valley.

Coming now to the larger work, the introduction of the high power engine has led to its adoption for traction purposes, in which the precedent was established by the Warren & Jamestown Street Railway Company, with a 1,000 horse-power plant operating the single-phase interurban railroad between Warren, Pa., and Jamestown, N. Y., as well as the city railway system. A similar plant of 2,000 horse-power was later installed at Olean, N. Y., and

FIG. 2.—SERVICE FROM PHILADELPHIA GAS-DRIVEN HIGH-PRESSURE PUMPING STATION

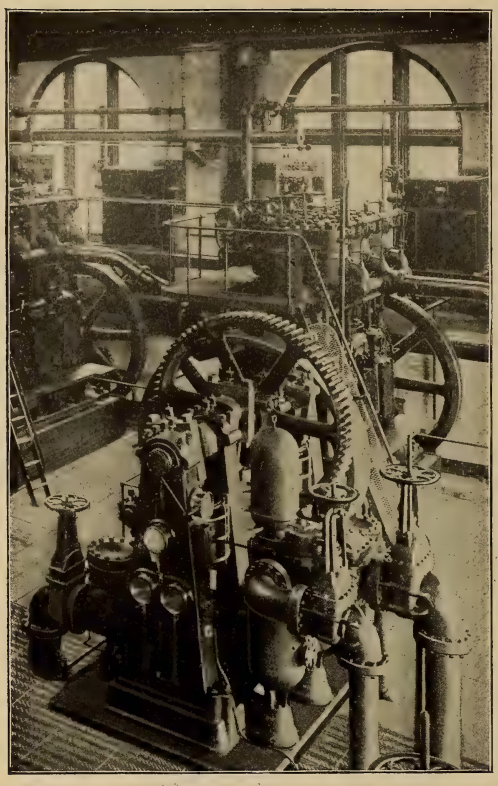


FIG. 3.—ONE OF THE 300-H.P. UNITS IN THE PHILADELPHIA HIGH-PRESSURE PUMPING STATION

a third, of 2,000 horse-power ultimate capacity, at Independence, Kan.

The possibilities in the use of "first distillate" gas from oil refinery stills early came under consideration. This gas is the richest known fuel for power purposes, varying in calorific value from 1,200 to 2,000 British thermal units per cubic foot. Practical experiments on a large scale with this gas has led to the 2,000 horse-power plant of the Atlantic Refining Company, Point Breeze, Philadelphia, Fig. 1, which has proven a successful plant from every standpoint. In blast furance gas work all conservative steel operators delayed for some time the introduction of gas engines using surplus blast furnace gas, but now much important work is under way. The most recent developments have taken place in the vicinity of Pittsburg, at the Edgar Thomson Works of the Carnegie Steel Company, where two 3,000 horse-power gas blowing units have been in operation since the first of the year and a third, for electrical power, has recently been put into commission. Thus, within the short space of ten years, covering the most active operations in the gas power field, the internal-combustion engine has immensely appreciated in value, not only as a prime mover *per se,* but also as a potent factor in meeting the growing necessity for a reduction in the cost of power generation.

Coincident with this development, the gas producer has put in appearance, and thus has opened up many new fields in the utilization of various kinds of fuel. In the summary above mentioned there were at the close of 1906 sixty-nine plants in operation, totalling 31,528 horse-power, or 485 horse-power on an average per plant. The installations range from 25 to 3,000 horse-power in capacity. Not all of these are in American territory, and in the list we find many foreign countries represented—England, Ireland, Canada, Mexico, Brazil, Argentine Republic, Spain, Egypt and Greece. A considerable number are located in the mining districts of the Western States, where fuel is necessarily expensive. The variety of fuels upon which producers are operating indicate the adaptability of the system—anthracite coal of various grades from pea to No. 2 buckwheat; bituminous coal from West Virginia, Pennsylvania and the Central States, as well as foreign coals, coke, charcoal and wood of various kinds, such as oak and Mexican mesquite; also peat and lignites. Producer equipment for the larger plants has been almost entirely confined to the pressure type with either continuous or intermittent working. Latterly, however, the suction type of producer has developed in considerable proportions, and now the suction type is available for con-

FIG. 4.—WILE SUCTION GAS PRODUCER, 200 H.P. INSTALLED AT THE COLUMBIA NUT & BOLT CO., BRIDGEPORT, CONN.

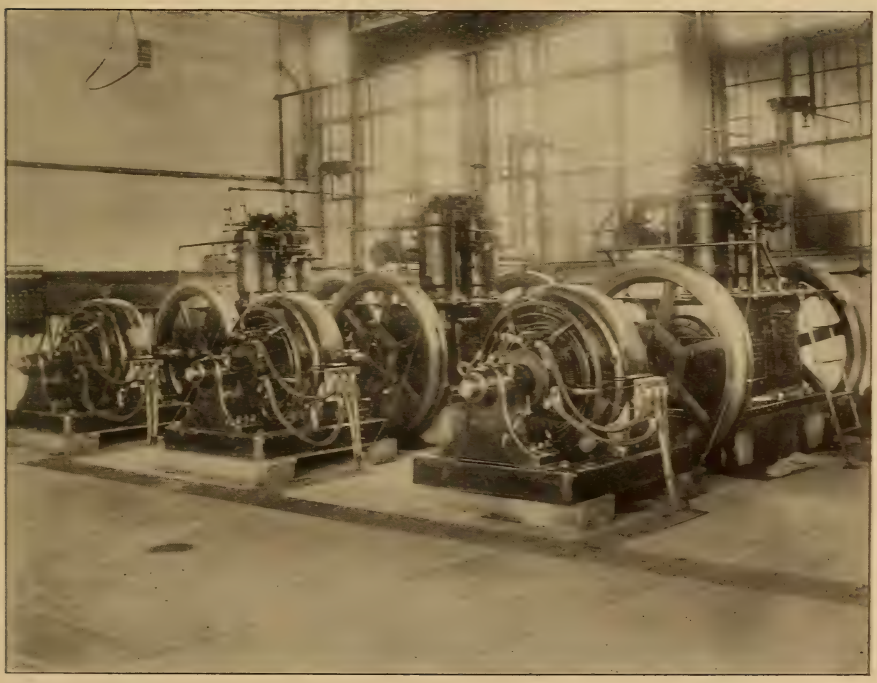


FIG. 5.—THREE 100-H.P. BRUCE-MERIAM-ABBOTT GAS ENGINES. THOMAS MOTOR CO., BUFFALO, N. Y.

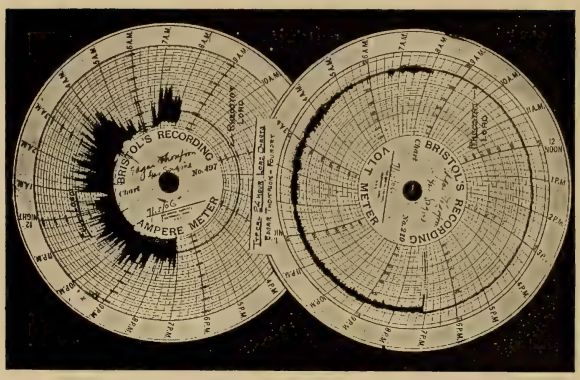


FIG. 6.—LOAD RECORD, 300-DAY TEST BLAST-FURNACE GAS ENGINE

tinuous working in sizes of several hundred horse-power.

For a number of years parallel operation of gas engine-driven alternators seemed to be considered more or less of a mechanical impossibility. With the present tandem double-acting type of gas unit the cyclical variation is sufficiently low to obviate entirely the use of spring couplings between engine and generator for either 25 or 60-cycle work. Solid couplings for 60-cycle units were proven practicable by experiments made in 1906 on a 500 horse-power Westinghouse unit originally provided with spring coupling. The springs in these couplings were blocked so as to provide a rigid connection, and the unit operated in parallel, as usual, without difficulty. Further, one igniter circuit was opened so as to "kill" one out of every four power strokes. Finally these units were operated in parallel with one cylinder cut off, representing an operating condition which it would probably never meet in practice.

In the case of one 60-cycle plant, equipped with spring couplings, it is reported that owing to a misunderstanding of the indications of synchronizing lamps on the switchboard, units were thrown in parallel several times in opposite phase without generators falling out of step.

It has generally been held that the

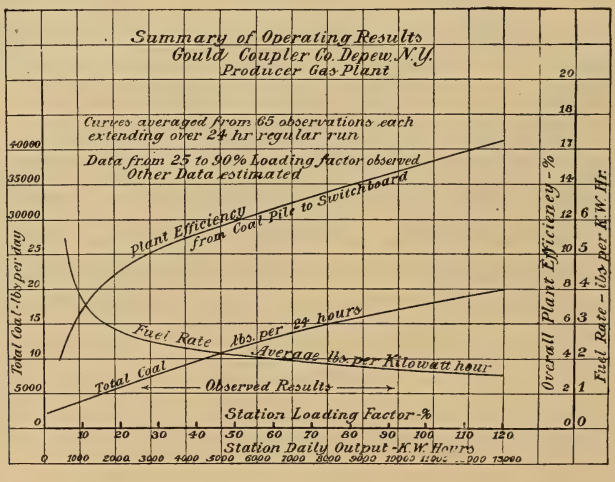

Summary of Operating Results
Gould Coupler Co. Depew N.Y.
Producer Gas Plant
Curves averaged from 65 observations each extending over 24 hr regular run
Data from 25 to 90% loading factor observed
Other Data estimated
Plant Efficiency From Coal Pile to Switchboard
Fuel Rate lbs. per 24 hours
Average lbs per Kilowatt hour
Total Coal
Observed Results
Station Loading Factor-%
Station Daily Output-K.W. Hours
Total Coal-lbs per day
Overall Plant Efficiency - %
Fuel Rate - lbs per K.W.Hr.

FIG. 7.—OPERATING RESULTS, GAS-POWER PLANT OF THE GOULD COUPLER CO., DEPEW, N. Y

depreciation on gas power properties is extraordinarily high. That this may be the case in instances of improper design and careless operation, is undoubted, but with reasonable care the gas engine of adequate design does not show to unusual disadvantage in this particular. An 800 horse-power central station operating at Bradford, Pa., on natural gas has been in operation for eight and one-half years, with repairs for the last two years of the period averaging only three-fourths of one per cent. ments covering a period of twenty years and nearly two-thirds of a million horse-power, indicate that the average actual life of this type of engine is from twenty-four to twenty-six years in the case of the steam engine, and somewhat less in the case of the gas engine, although the records cover a period of only eleven years. Further, repair bills on engines actually in service represent less than 1½ per cent. of the value of the product in the case of steam, and somewhat over 2 per cent. in the

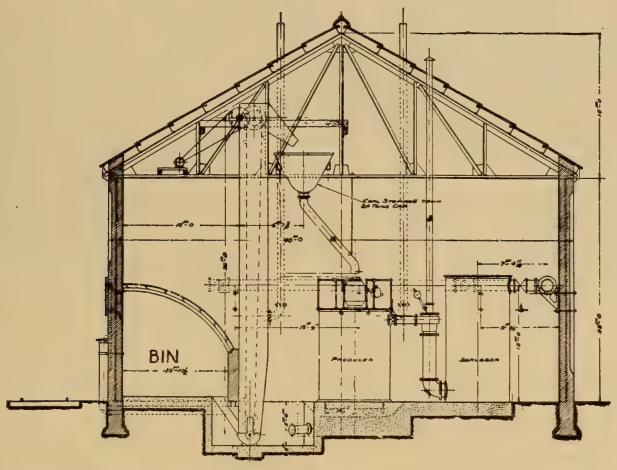


FIG. 8.—TYPICAL PRODUCER PLANT ARRANGEMENT. THE FIRTH-STIRLING STEEL CO., WASHINGTON, D. C.

on the original investment. This represents the result of intelligent operation and reasonable care. In another instance, a 1,000 horse-power central station operating in the Mexican highlands on wood producer gas, the average annual repair bill on the entire power plant for four years of service was exactly one per cent. of the original investment.

The general question of probable life, upon which physical depreciation is determined, is a difficult one. Some light is thrown on the subject by data pertaining to the product of the Westinghouse Machine Company, representing the majority of its gas engine business—the vertical, single-acting type engine. Records of shipments, repairs and replace- case of the gas engine. These are materially better results than are credited generally to the gas power plant. Assuming an average life of twenty years, this represents 5 per cent. straight depreciation. On the sinking fund basis, at 4.5 per cent. interest, the depreciation rate is only 3.187 per cent. In considering the depreciation of the producer equipment alone, it must be borne in mind that the latter represents only about one-fourth of the total valuation of the plant, and hence the effect of even a higher rate of depreciation would not preponderate in the final financial result. There often arises the question as to the comparative operating qualities of steam and gas engine equipment. The following

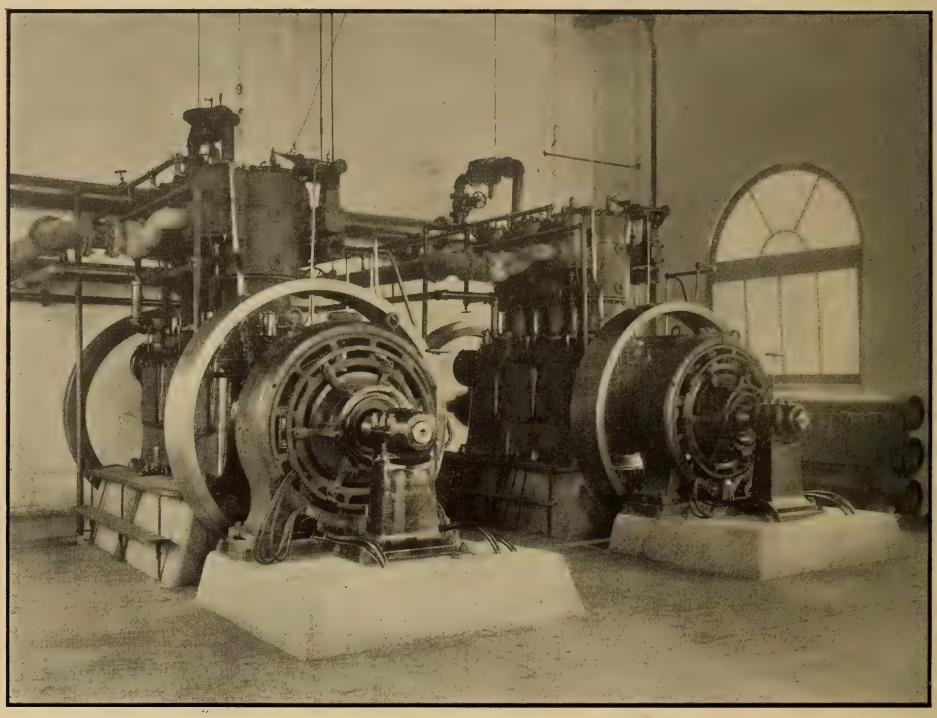


FIG. 9.—TYPICAL ENGINE ROOM FOR MEDIUM SIZED PLANTS. THE FIRTH-STIRLING CO., WASHINGTON, D. C.

data may throw some light upon this subject. The 4,500 horse-power gas power plant of the Iola (Kansas) Portland Cement Company contains three 500 horse-power horizontals and fourteen vertical units, the latter averaging 214 horse-power each. During a typical four months' run (January to April, 1907), the horizontal units operated on an average of 95.6 per cent. of the elapsed time, the 300 horse-power verticals 98.4 per cent., and the 140 horse-power vertical 97.5 per cent. of the elapsed time. The total period of shutdown for repairs only averaged 0.63 per cent. for the horizontals and 0.48 per cent. for the large verticals. Thus, these horizontal units, which represent the latest type of gas-driven equipment, operate on the average 23.17 hours per day, and under rather severe conditions, owing to the continual presence of cement dust in the atmosphere.

During the early experimental work on blast furnace gas at the Carnegie Steel Works, near Pittsburg, a 500 horse-power engine was subjected to a thirty-day continuous test, with the following results:—Load was carried 99⅓ per cent. of the total elapsed time, or 730 hours. Two stops were recorded, one on account of lack of gas and another to tighten a leaky water plunger. Only 0.5 per cent. was chargeable to stops for repairs. The accompanying load charts show the character of load sustained during this period—a fluctuating foundry load, with peaks running well above rating, with momentary swings to 25 per cent. overload, and now and then a 10 per cent. overload period lasting as long as fifteen minutes. During some of the time rheostat load was carried at night, and the better regulation is due to overcompounding a generator, the effect of which only appeared during the fluctuating load.

The following operating results

are cited as typical of those obtainable with standard equipment: First, the traction station of the Warren & Jamestown Street Railway Company, 90 per cent. of the time on a load of which the illustration is typical. This plant consumes, on an average, 21.9 cubic feet of natural gas per kilowatt-hour at an average total loading factor of but 37 per cent. of the capacity. With the price of gas equivalent (on a heat basis) to $4.05 coal, the cost of running the entire plant, both city and suburban systems, totalling 300 car-miles, or 40,000 ton-miles per day, averaged for four months only $12.75 per day. At the above loading factor, the operating cost, including fuel, wages, oil and miscellaneous repairs and supplies, was slightly over $\frac{3}{4}$ per cent. per kilowatt-hour at the switchboard.

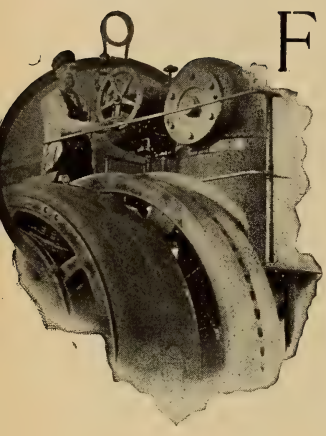
The accompanying diagram shows the operating efficiency over a wide range of loading factor of a 450-kilowatt, three-unit power plant operating the works of the Gould Coupler Company, Depew, N. Y. This plant operates on producer gas from bituminous coal, and gives continuous service twenty-four hours per day, six and one-half days per week, on a load averaging about 70 per cent. of the capacity, with fluctuations to 15 per cent. overload. At this load, and a coal consumption of 1.8 pounds per kilowatt-hour, the cost of power during six months of 1906 averaged 0.67 per cent. per kilowatt-hour operating, or 0.95 per cent. per kilowatt-hour, including fixed charges. This is equivalent to an annual power cost of $24 per horse-power-year, ten-hour power, or $57 for twenty-four-hour power.

Even better results have been obtained from a 500 horse-power bituminous producer gas plant operating the works of the Norton Company, Worcester, Mass. This plant operates ten hours per day. An average of fourteen weeks' operation, at a loading of 75 to 80 per cent. rating showed a total coal consumption for all purposes of about 2 pounds per kilowatt-hour, or less than 1.5 pounds per kilowatt-hour, excluding 10 per cent. fuel for rebuilding fires on Sunday. For a medium-sized industrial plant, a good design for producer house is shown in the section of power plant of the Firth-Stirling Steel Company, Washington, D. C., which furnishes power for the ordnance department of this works.

LARGE GAS AND STEAM ENGINES

By W. H. Booth, M. Am. Soc. C. E.

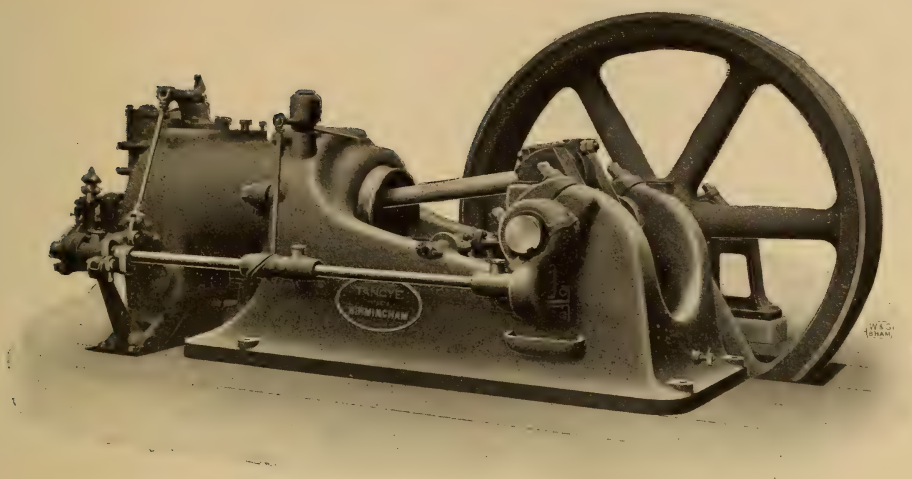
I. LARGE GAS ENGINES.



FOR some time there has been a considerable discussion of the relative merits of the ordinary steam engine and of the steam turbine, and unthinking people, who have waited seventeen years before putting any belief at all in the turbine, are now busy tumbling over one another to get to the funeral of the reciprocating engine, much to the amusement of the more thoughtful who have given a helping hand to the turbine without losing their heads now that it has suddenly attained a position of importance. It is doubtless true that the turbine can be made to do service in situations which give it an incontestable superiority over reciprocating engines, and it is possible, with care, so to balance the turbine that it will rotate round its center of gravity and so produce no vibration, though some makers do not apparently always care to attain this result. But just when the turbine was receiving the recognition that it should have received years ago, so another prime mover—the internal combustion engine—had also come to be regarded seriously and this, too, years after its necessity was pointed out by those who understood what was meant by the waste of gas that was going on all over the country in the shape of blast furnace gas burning to useless destruction. Germany, Belgium and to some extent the United States have realized this waste for several years past, and, as a result, there are great numbers of large gas engines made in Germany and Belgium, and our British makers, so late in the field, have contented themselves with following as best they could, and even yet have not been able to persuade very many ironmasters to their views as to using waste gas. Still the large gas engine is making genuine progress and it is being made by several very prominent firms. As regards the fuel consumption of gas and of steam engines, there seems very little doubt that the gas engine will work for about one-half the fuel consumption of the best steam plants. Now in face of a saving of half the fuel, not to name the possibility of using fuel of an inferior quality, the question of the reciprocating engine as against the turbine assumes an altogether different complexion from what it does when it is a mere question of comparison between a turbine and a steam engine running a dead heat as regards fuel consumption.

Even if we assume that the turbine has a special field in the ocean steamer, this does not furnish an argument for land purposes, and it is by no means certain yet that the internal combustion engine may not win a place on the ocean.

The writer stated recently before a Parliamentary committee that he could find no physical or mechanical reason why the gas engine should not be made in sizes as large as the steam engine. The Germans are known to be examining the boiler question with a view to finding some boiler that will provide a sufficient

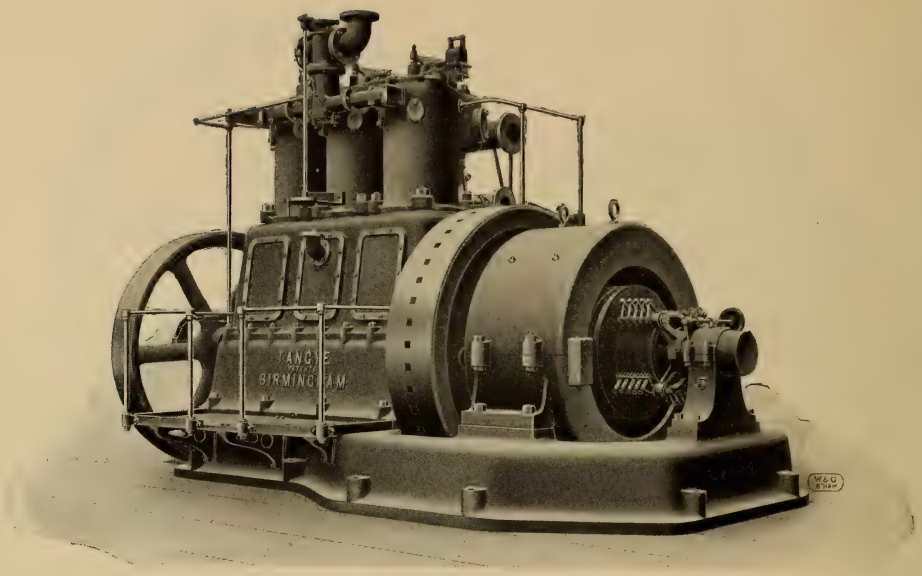


HORIZONTAL GAS ENGINE, BY TANGYES, LIMITED, BIRMINGHAM

ratio of grate surface to total floor space to enable them to put a ship on the Atlantic that will eclipse the *Lusitania* and her sister vessel. Given the gas engine as large as the steam engine, even if it should be of greater weight per horse-power, it is scarcely likely that the combined weight of engines and gas producers will exceed that of steam engines or turbines and boilers. A great difficulty with steam plant is the getting of fuel to the boiler furnaces. Hence the advantage of oil fuel which can be so readily conveyed mechanically and burned without labour. It is possible to arrange conveyors to gas producers that will obviate the trouble now found with stoking, while avoiding the cost of oil.

Weight for weight, oil is nearly twice as efficient as coal. Weight for weight, the fuel used in gas engines is doubly as efficient as fuel used in steam plant. There are thus presented for the near future a set of interesting problems of power production for the marine engineer of which the more difficult features, such as the manufacture of a poisonous gas in a confined hold, the height of a producer, and other points of difficulty are entirely absent in the large shore generating station. The reciprocating engine, so often declared to be as extinct as the dodo, appears to have secured a new lease of life in the fact that its thermo-dynamic efficiency, when gas driven, is so very much higher than that of the steam engine can hope to be, and, in view of the recognition of the fact that gas engines are not tied to small dimensions by any latent defect of principle, but are only small until some maker gets an order for a large one that will pay for the construction of larger patterns.

Because they are not equipped with turbines, certain power stations have been denounced as obsolete, and by none, perhaps, so freely as by those who have been most tardy in recognizing merit in the turbine. But except that the method of generating steam is obsolete in the fact that there is no scientific attention to the all important question of superheat, a power station can scarcely be termed obsolete simply because it is not filled with a lot of hustling and screaming turbines, though all steam driven stations may in a sense be more rightly termed obsolete in comparison with a gas-driven station, because, in a modern station, it is in fuel that expense must be saved, fuel being one of the largest items in a steam station,



VERTICAL THREE-CYLINDER ENCLOSED GAS ENGINE. TANGYES, LIMITED, BIRMINGHAM

though of much less moment in a gas-driven station provided with by-product recovery plant. The saving of the by-products from bituminous fuel may be a most important item in the economy of running a station. Thus, as between a power station in London and one in the Midlands, the cost of coal may be one-half or even a third less at the Midlands station. As between gas and steam power, the cost may be again halved by the superior thermo-dynamic efficiency of the gas engine, and finally, one-half of the cost of fuel at the gas power station may be returned in profit from by-products, all of which accumulated economies are to be set against the line-loss of long-distance transmission of the generated electricity, for a gas station and by-product plant would only be less undesirable, from an æsthetic point of view in London, than a steam station.

Considering the various ways in which steam and gas engines may therefore enter into rivalry, it would appear that the time has come for these two prime movers to be considered together. They bear very much the same general shape, they are both limited in size by the same feature, namely, the crank shaft, on the cost and size of which depends so much any further increase in the size and power of either a gas or a steam engine, while the large maintenance cost of gas engines, where high explosive gas is employed, is an unnecessary charge that has been handed down from the early days of the gas engine when illuminating gas of 650 to 800 B. T. U. capacity per cubic foot was the only gas available. Subsequent to the use of town gas, cheaper and poorer gases have been employed, but there has always been an endeavour to render the poor gas as explosive as possible. Its thermal value has been kept up as high as it could be secured and its rapidity of combustion or explosive action has been maintained by a large admixture of hydrogen.

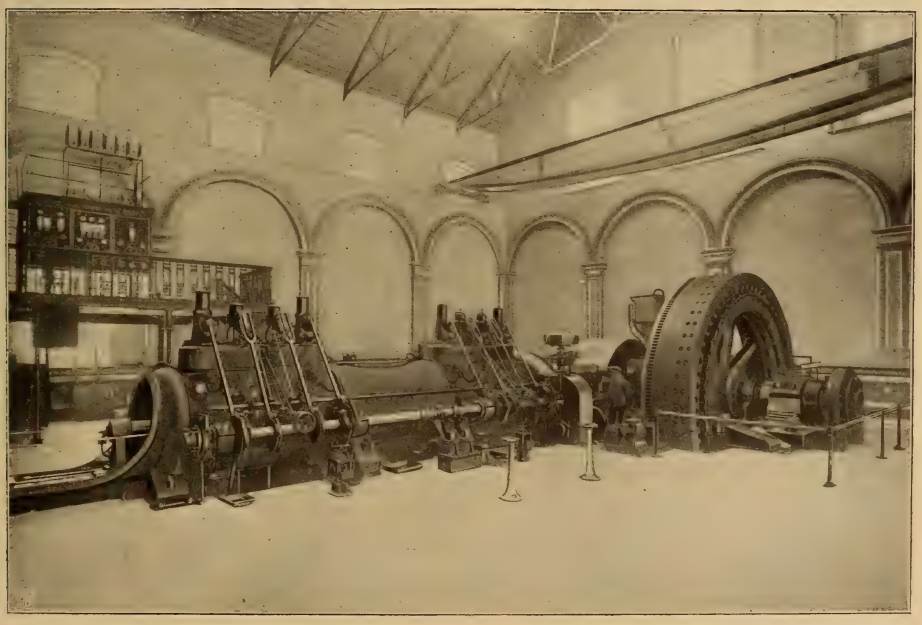
The erroneous idea has been held that it was essential that the fullest possible pressure should be produced at the dead point of the crank, for this was proof of the generation of the heat at maximum temperature and insured its working through a

maximum piston travel. But, in thus arguing, certain very important factors were overlooked.

In the first place, it was forgotten that at the dead point of the crank the pressure on the piston is doing—can do—no work. Yet at that time the crank pin and the crank shaft bearings are rotating at their full velocity and all needless pressure only exerts a braking effect.

Secondly, a gas engine has a water-cooled cylinder and it is obviously a mistake, as regards the cylinder, to produce a maximum temperature and maintain the highly heated gases tightly compressed between the cooled faces of the cylinder cover and the piston at a time when the latter is standing at rest or moving very slowly. The only result is to communicate an unnecessary amount of heat to the jacket cooling water. It should not be forgotten that the water jacket is not meant for the purpose of abstracting heat from the working gas, but is intended to prevent overheating of the metal of the cylinder and piston. Consequently it is proper to cause a slow ignition which, when the ratio of compression of the charge is high, will not produce a pressure in the cylinder very much higher than that of compression. The slowness of the ignition, however wrong by the theory which demands the addition of all heat at an early stage, is correct in practice, because instead of the water jacket being heated, the heat is promptly converted into work behing a moving piston. The internal combustion engine is so entirely a matter of judicious compromise that it is not possible to draw conclusions and establish axioms on any rigid academic theory which is not supported by the necessities of practice.

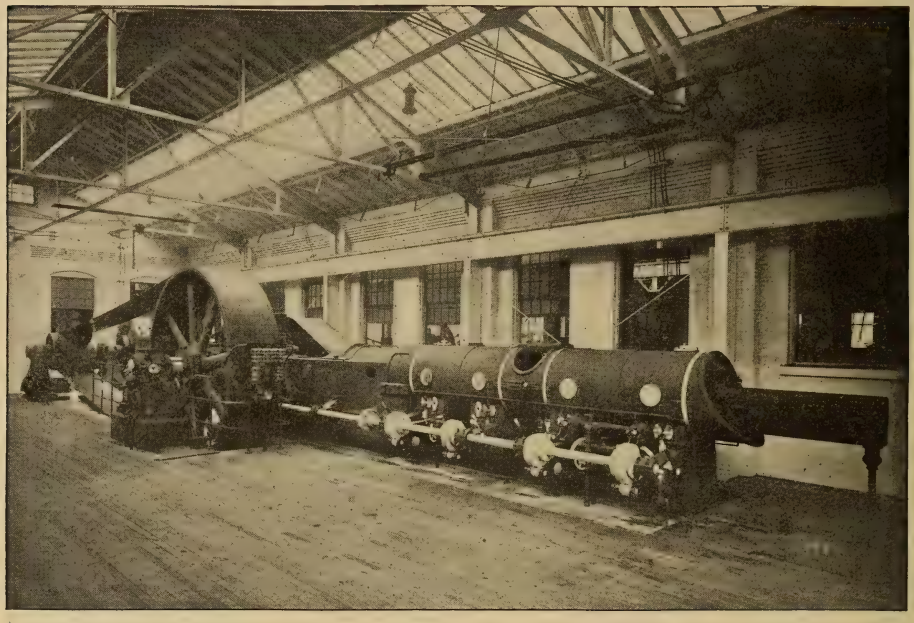
Thus the best gas engine practice demands a gas of moderate calorific capacity—not exceeding, say, 120 B. T. U. per cubic foot, and it may be here added that the waste gases of the blast furnace on which the reputation, nay, the every existence, of the large gas engine has been built up, do not exceed 100 B. T. U. capacity per cubic foot, and are found



NURNBERG DOUBLE-ACTING SINGLE TANDEM GAS ENGINE, 1,200 H.P., DRIVING 825 K.W. THREE-PHASE ALTERNATOR, AT POWELL DUFFRYN STEAM COAL CO.

as low as 90 B. T. U. Yet, such very poor gases never fail to ignite and they give an impulse to the piston as gentle as that given by steam, though with a higher mean pressure per square inch than appears in the steam engine. Such higher mean pressure means nothing more in construction than that for a given set of working parts, such as piston rod, connecting rod, and shaft, the cylinder of a gas engine would be proportionally reduced in area so that the total piston plugs in order more rapidly to spread the flame through the charge.

Where, formerly, all gas engines only made one explosive stroke in four, being single acting and on the Otto cycle, large engines are now double acting, no difficulty being found with rods and glands which are suitably water jacketed, and this arrangement at once gives one working stroke for each two strokes of the piston; while when separate gas and air pumps are added, an engine will

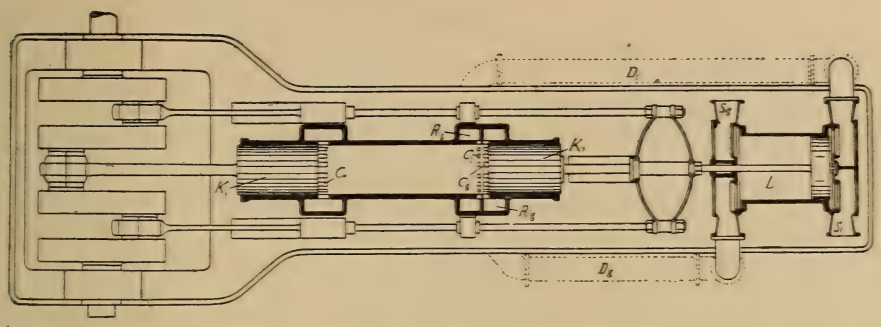


SARGENT ENGINE CO., 500 H.P. ENGINE, 300 K.W. DIRECT-CURRENT GENERATOR

load may be the same as in a steam engine with such rods and working parts.

There is therefore no reason with suitable gas to fear excessive depreciation. With the large gas engine the difficulties are in some cases less than with small engines. Thus with a large engine the exhaust valve can be water cooled, for it is large enough to admit of what could not be done with the valve of a small engine. If ignition proves too slow in a very large cylinder, there is nothing to prevent the use of more sparking plugs in order more rapidly to spread the flame through the charge.

Where, formerly, all gas engines only made one explosive stroke in four, being single acting and on the Otto cycle, large engines are now double acting, no difficulty being found with rods and glands which are suitably water jacketed, and this arrangement at once gives one working stroke for each two strokes of the piston; while when separate gas and air pumps are added, an engine will make two working strokes per revolution. The mechanical efficiency may therefore be expected to be nearly equal to that of the steam engine, for the low mechanical efficiency of the gas engine of the four-stroke type was simply due to the fact that, as a machine, it was so very much too large for its work because it did useful work on only one-fourth of its strokes. Neglecting the compression pumps, the fully acting gas engine, having a mean pressure higher than that of a steam engine, need not have a less mechanical efficiency, and the



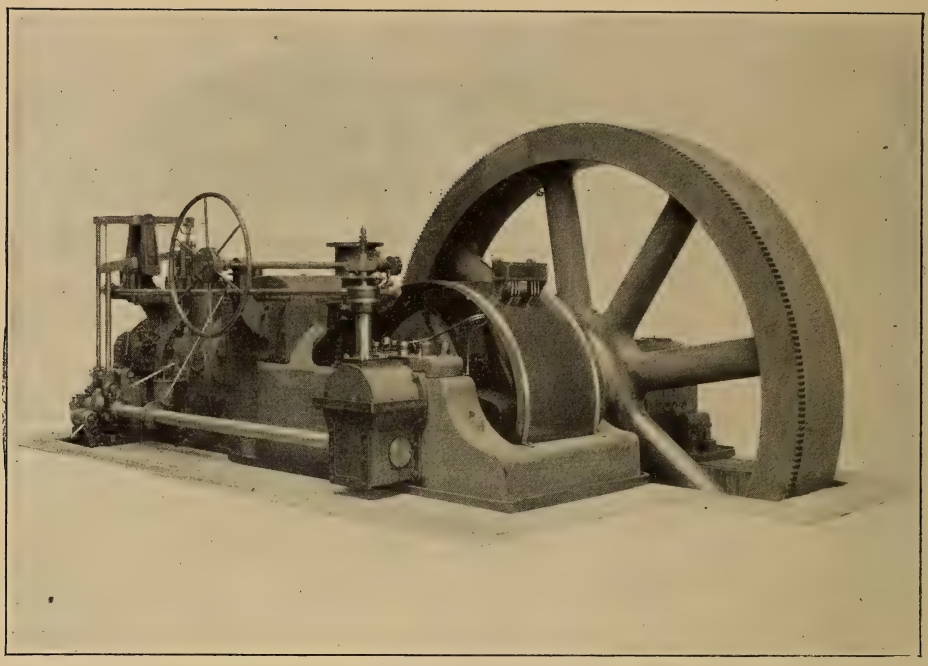
GENERAL ARRANGEMENT OF OECHELHAUSER GAS ENGINE

two machines may therefore be considered together. Meantime, the gas turbine is luring on inventors, but, while one would not say it is an impossibility, it is yet far outside the sphere of commercial practicability. The turbine compressor is still in the experimental stage, so that even if there were a good gas turbine there would be needed large reciprocating compressors. The immediate future for gas power must therefore lie with the present form of reciprocating engine, which, with its double effect from fuel, as compared with steam, can hardly be passed over even for all the claimed advantages of the steam turbine.

Of the so-called two-cycle gas engines, the Oechelhauser engine may be cited, since though not the first gas engine to be driven by blast furnace gas, it was the first large engine to be so driven, the first actual engine being that at the Wishaw works of the Glasgow Steel & Iron Company, which was put down to work in the pioneer blast furnace plant of the inventor, Mr. B. H. Thwaite, and tested by the writer, before any other engine was at work.* In the Oechelhauser engine there are two pistons in one cylinder, both attached by suitable rods to the same crank shaft, with cranks at 180 degrees apart. Air and gas are supplied by the pump *L* at a pressure of 7 pounds to 5 pounds per square inch. The exhaust ports *Ca* are uncovered by the piston *K*, and gas and air enter by the ports that are uncovered by the other piston *K2*. There is therefore a fair length of cylinder as a safeguard against serious loss of gas by way of the exhaust. The pistons approach each other and compress the mixed charge and are driven apart by the explosion, and there is therefore a working stroke each revolution.

It will be observed that since both pistons are in one cylinder the relative piston movement is doubled and expansion is rapid, so that there is less heat absorption by the jacket. With 60-pound mean effective pressure the diameter of a cylinder of 1,000 B. H. P. is 36 mm.; the reciprocating parts are perfectly balanced and there is no tendency to move the cylinder, on which no end stress of pressure can come; nor is there any stress on the shaft bearings, for the two pistons pull exactly oppositely upon the shaft, and relieve both bed plate and cylinder of all duty except that of guiding the pistons and containing the working gases. For this reason the crank brasses are two-part only, the customary four-part brass of the ordinary horizontal steam engine or gas engine not being required It will be observed that one piston is connected to the crankshaft by an ordinary connecting rod and that the opposite piston has a wide cross-head and a pair of long side rods and two connecting rods so that this cylinder pulls on two cranks, and its equivalent pull is exactly in line with the

*An illustration of this original blast-furnace gas plant is shown on page 27.



PREMIER GAS ENGINE, 250 HORSE-POWER

pull of the other piston, and there is consequently no horizontal twisting effort on the framing.

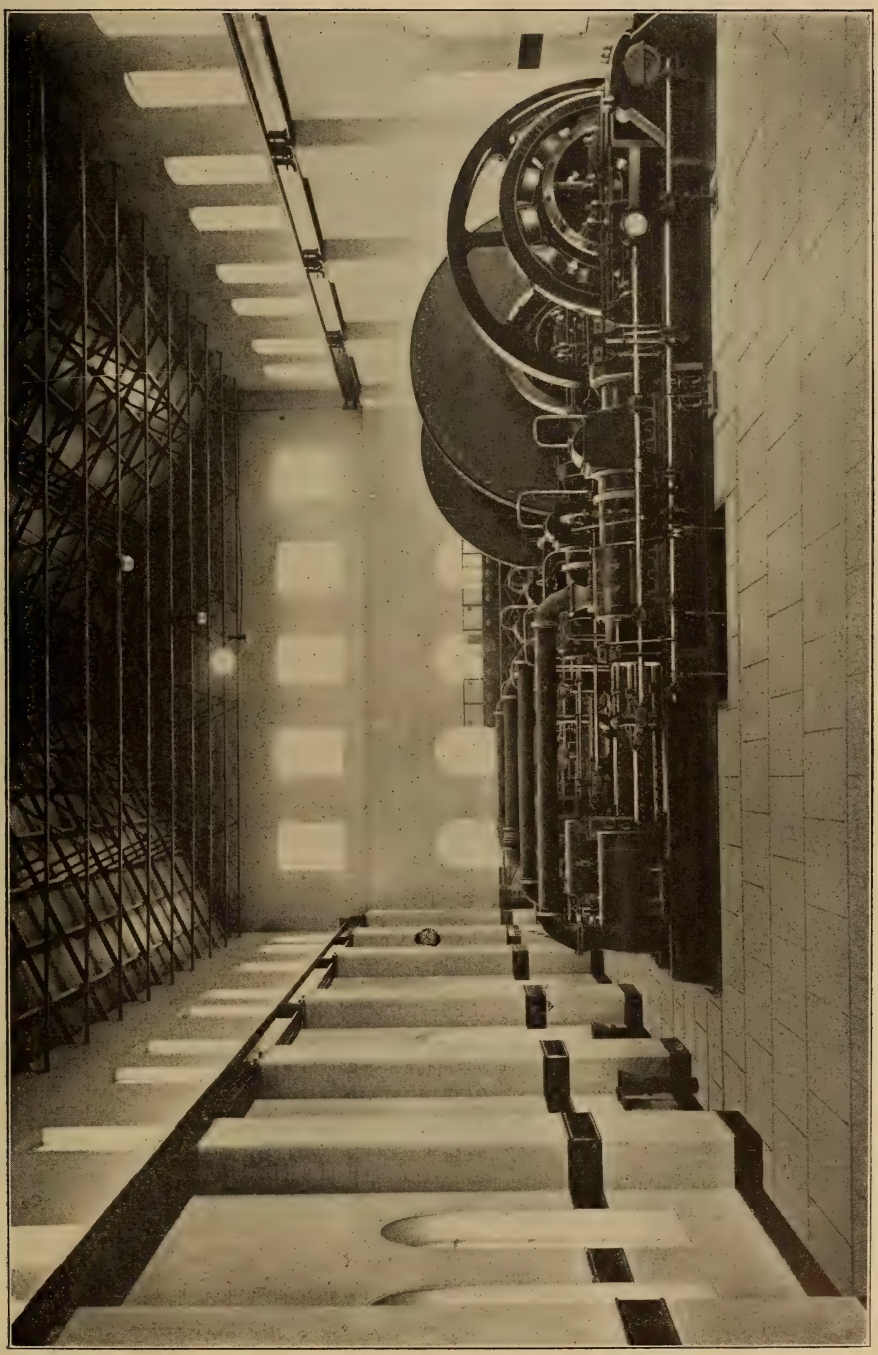
An engine normally rated at 1,000 horse-power will have a length of 54 feet, a breadth of 15 feet, without flywheel, and a speed of 95 revolutions per minute, but at maximum capacity a 500 horse-power engine has developed 700 with gas of 100 B. T. U. capacity per cubic foot.

For the driving of alternating-current dynamos in parallel, several engines have been made to run within a variation of 1-250 with no other flywheel effect than that of the armature, and ordinarily for satisfactory parallel running an engine of 1,000 horse-power requires a wheel of only 28 tons.

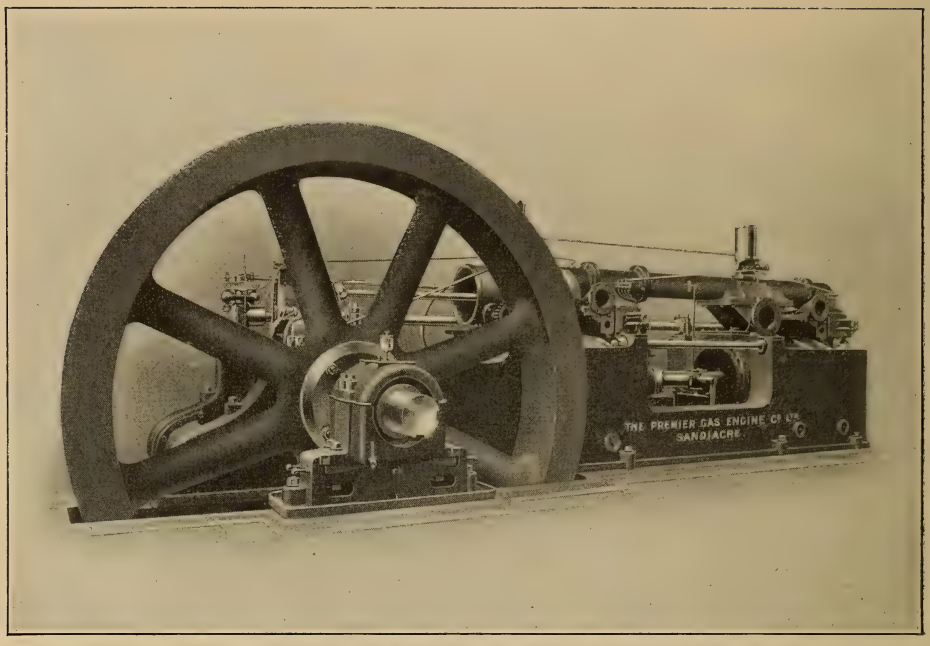
On page 163 is the general arrangement of the double engine, 3,000 horse-power size, for driving an alternator of 1,375 KW.

Using blast furnace gas of 100 B. T. U. capacity, one indicated horse-power at full load will require 72 cubic feet of gas, or 90 feet per brake-horse-power. The heat consumption is 7,200 B. T. U. per I. H. P. hour, and at 80 per cent. mechanical efficiency this represents 9,000 B. T. U. per B. H. P. Mr. Marshall Downie gave some figures of costs of engines, turbines and gas engines as follows: Fuel cost per kilowatt-hour in pence for steam was, in four instances of engines 240 to 5,000 I. H. P., 0.17, 0.161, 0.17 and 0.14, the last figure being for a triple expansion Sulzer engine with 223 degrees F. of superheat, the other three being without superheat. For three steam turbines, 300 to 3,000 I. H. P., the figures of fuel cost per kilowatt-hour were 0.17, 0.180 and 0.15 with a superheat of 30, 81 and 212 degrees F., respectively. The same figures for four gas engines of 380 to 886 I. H. P. were 0.083, 0.084, 0.080, and 0.070 pence.

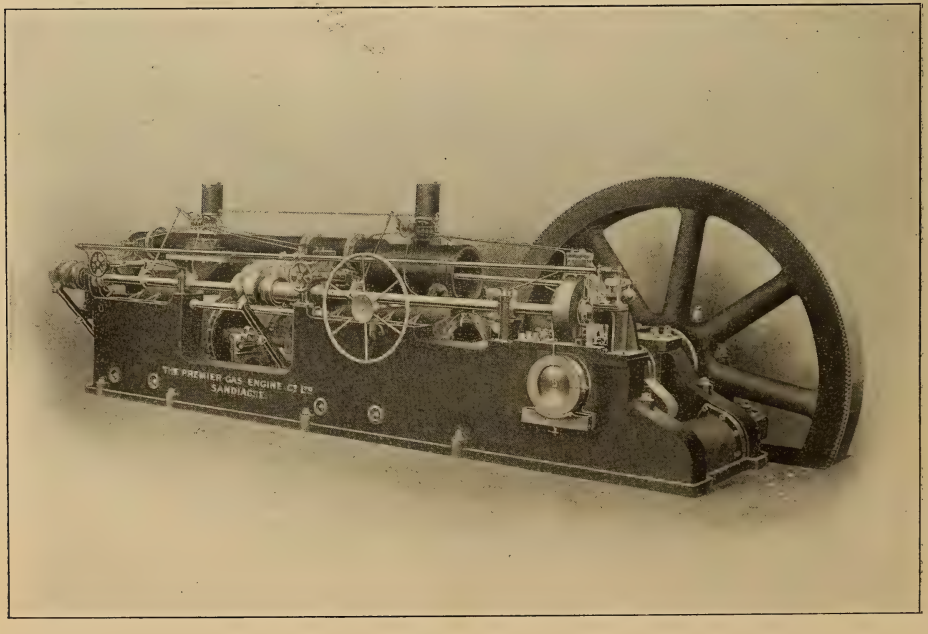
The total working costs for a 30 per cent. load factor were similarly shown to be for steam engine plant of 6,750 KW., 0.739d., for steam turbine plant 0.72d., for gas engines



OECHELHAUSER GAS-POWER DYNAMO SETS, 3,000-H. P. UNITS. T. BEARDMORE & CO., GLASGOW



PREMIER GAS ENGINE, 12,000-H. P. TANDEM SCAVENGER TYPE

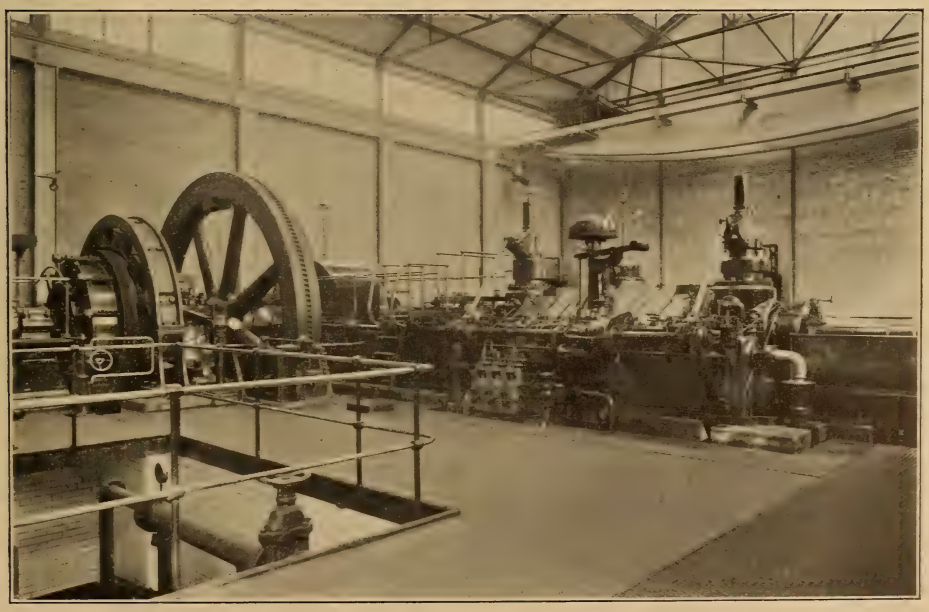


PREMIER GAS ENGINES TANDEM SCAVENGER TYPE

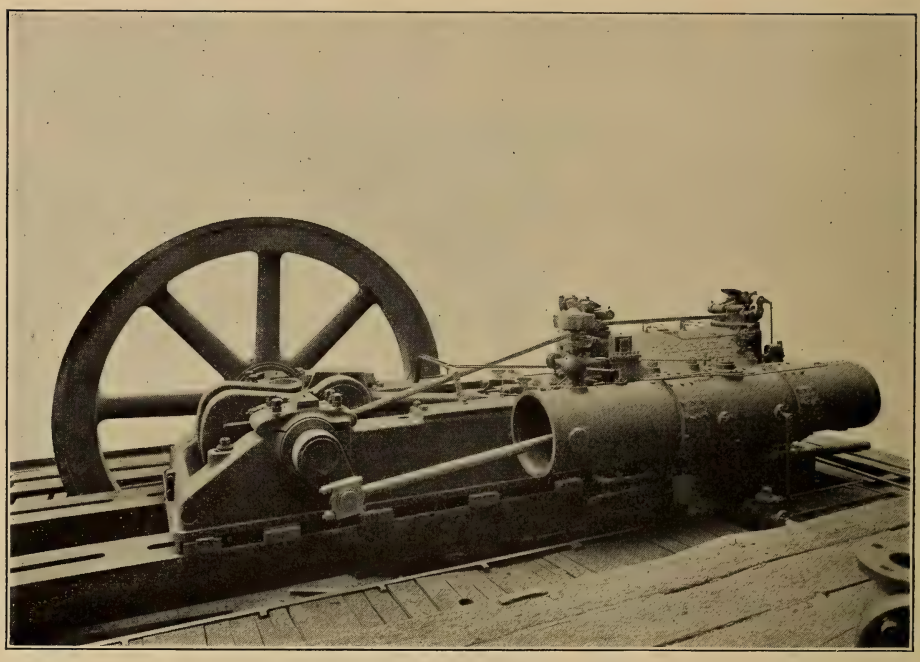
without recovery of by-products 0.61, and with recovery 0.54. These figures at a 60 per cent. load factor become respectively 0.539, 0.53, 0.41, and 0.36 pence; figures which substantiate those put forward before the Select Committee on London Power Bills for the Coal Fields Scheme of Gas-Generated Electricity, put forward by the Messrs. Lupton, Thwaite and the author. The Oechelhauser gas engine is made in Great Britain by Messrs. T. Beardmore & Co., of Parkhead Forge, Glasgow. The air and gas pump is usually placed tandem with the working cylinder and delivers gas and air from its opposite ends. Some of the air acts as a scavenging charge; the fact that the working charge enters by the ports so far removed from the exhaust port is a safeguard against loss of charge. Thus air first enters and clears away the burnt gases; then the gas ports are uncovered and both air and gas enter and mix. Governing is effected by means of a by-pass return, whereby at lighter loads some of the gas sent forward by the gas pump is returned, thus diminishing the volume furnished to the cylinder. There is always a correct mixture formed at all loads.

Water jacketing is complete round the cylinder and valve chambers.

Though several makers of large gas engines in Great Britain are making engines from German designs this need not be thought surprising, since by their prompt acceptance of Thwaite's pioneer work the Germans have been able to secure the earliest benefits from using blast furnace gas; and Mr. K. Reinhardt, in his paper read at a recent meeting of the Iron and Steel Institute, stated that there were no fewer than twenty-nine firms in Germany that were making large gas engines and, of forty-nine German iron smelting works, thirty-two had already engines at work and nine other firms had ordered engines and there were at work engines aggregating 385,000 horse-power in March, 1906, and 36,150 horse-power more was ordered before July 1 of that year. At one works no less than 35,000 horse-power was at work. Nevertheless, all English makers have not gone abroad for designs. The



KOERTING GAS ENGINE OF 750 H. P. BUILT BY MATHER & PLATT, LTD.

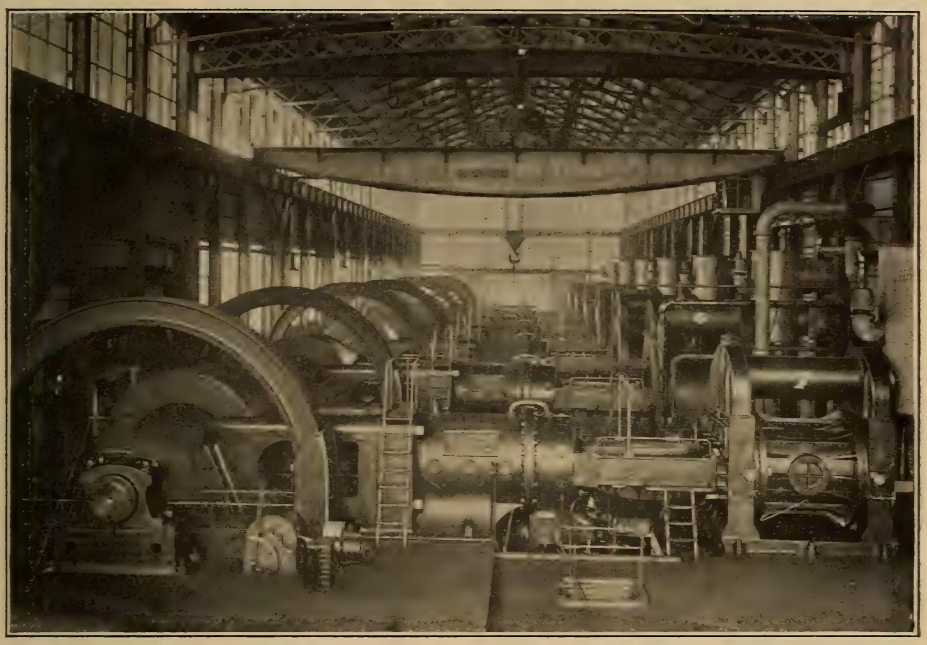


IMPROVED MATHER & PLATT KOERTING GAS ENGINE

Premier Gas Engine Company, of Sandiacre, near Nottingham, have long made gas engines of successful types, and are prepared to make engines of 2,400 I. H. P., and in the matter of such things as water-cooled exhaust valves and pistons, the Premier Company were ahead of Continental practice. They also adopted the valve arrangement, now becoming standard Continental practice, as long ago as fourteen years. The Premier Company adhere to the system of scavenging by means of a positively forced charge of air through the compression chamber, a precaution that is perhaps more important where rich gases are employed than in case of such poor gases as the blast furnace variety. The scavenging air is supplied by the front piston which, being larger than the working piston, draws in air at the valves and sends it through the cylinder on the return stroke so that the freshly drawn charge has only to mix with pure air. Thus the engine is of the four-stroke variety with a scavenging charge that assists towards higher compression by the cooling effect it exercises on the valves and cylinder spaces.

One of the illustrations shows an engine of 250 horse-power, and will suffice to show the class of engine and weight of the design. Governing being by the blade and stepped plate as shown, the governor has no work to do beyond swinging the blade. The 1,200 horse-power size with two tandem cylinders is also shown. As regards dimensions, an engine of 250 I. H. P. will run at 150 revolutions per minute and will have over all dimensions 18 feet 6 inches × 10 feet 6 inches × 12 feet, according to type.

A firm who, on the contrary, have adopted a continental design is that of Mather & Platt, the English makers of the Körting engine, which they took up about three years ago. This engine is of two-cycle type and also double acting, so that every stroke is a working stroke by aid of the pumps for air and gas which practically give the Clerk cycle of working and make as much of the working cylinder as can be made.

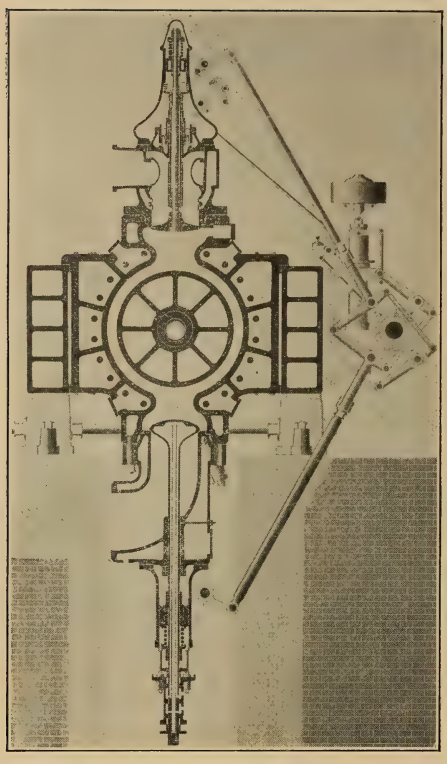


SEVEN COCKERILL BLOWING ENGINES AT THE CARGO-FLEET IRON WORKS, 800-H. P. UNITS. RICHARDSON, WESTGARTH & CO., MIDDLESBROUGH, ENGLAND

At first the construction adopted did not materially differ from that of the engine as made in Germany, but in the light of experience since gained considerable departures have been made from the old design with a view to simplification, efficiency, compactness, and suitability for working successfully with producer and coke oven gas.

An intermediate design was brought out by Messrs. Mather & Platt, Ltd., in 1905, in which the side shaft employed for actuating the admission valves was brought over to the same side of the engine as the charging pumps and driven by screw gear instead of by bevel wheels, thus reducing the width. But it is in the 1906 type of engine that the most striking

COCKERILL DYNAMO ENGINE AT CARGO-FLEET IRON WORKS, 500 H. P. RICHARDSON, WESTGARTH & CO., MIDDLESBROUGH

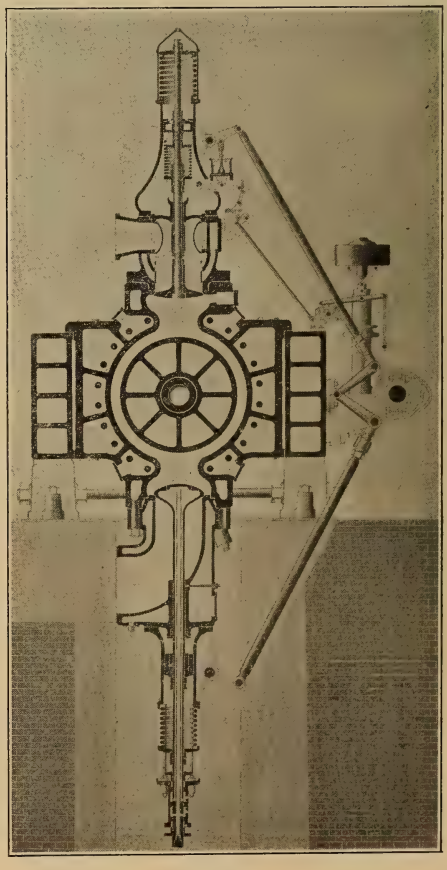


COCKERILL VALVE GEAR AS ARRANGED FOR VARIABLE ADMISSION

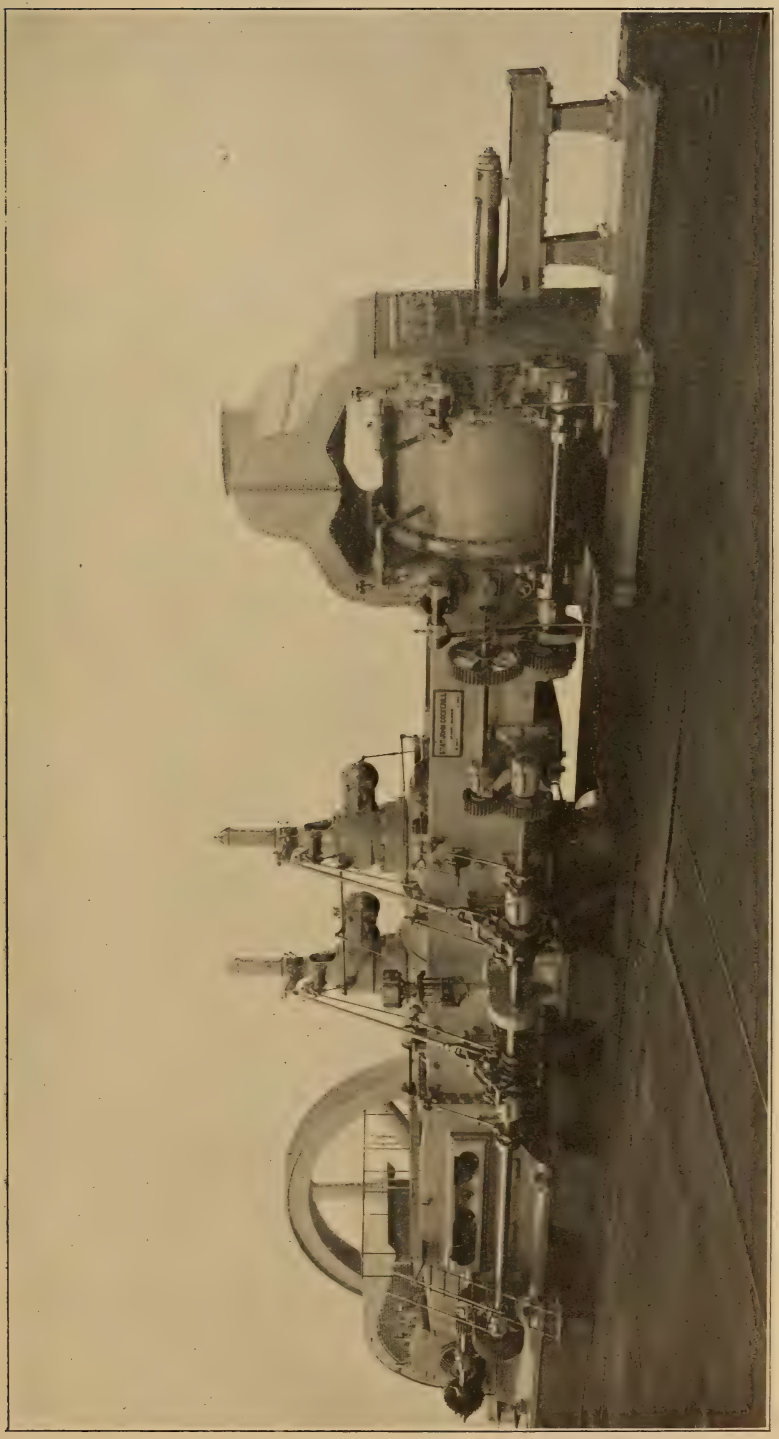
improvements have been introduced, by which the size and weight have been further reduced, and the construction and working of the engine rendered more simple.

In this latest design there are only two operative valves on the engine and these are worked by the simple method of an eccentric, on the main crankshaft, which works special lever gear with rolling contact through a connecting rod; by this alteration the side shaft, cams, bearings and gear wheels employed in the original design are all eliminated. The charging pumps also have been altered in arrangement and simplified, there being in the new design one double-acting gas pump, which has been placed between and in line with two single-acting air pumps. The pumps are separated from each other by intermediate delivery valve boxes, the valves are all automatic in action and of simple nature, which renders their replacement very easy.

Already the engine has been built to do 1,200 horse-power from a single cylinder and engines are in course of construction capable of developing many thousands of horse-power. So far as possible this engine is built on the lines of the steam engine. These engines have an outside cross-head, thus keeping the cross-head pin as cool as possible. The charging pumps are alongside the main cylinder. The air pump sends forward a scavenging charge, after which air and gas enter together, mixing at the admission valve. The general arrangement shows very clearly the central ring of ports arranged to serve both ends of the cylinder by means of the long piston which uncovers this central



COCKERILL VALVE GEAR AS ARRANGED FOR CONSTANT COMPRESSION



COCKERILL GAS-POWER BLOWING ENGINE AS BUILT BY THE JOHN COCKERILL WORKS, SERAING, BELGIUM

band of exhaust ports at every stroke and renders unnecessary any special exhaust valve, while at the same time the exhaust passage is well enveloped in the water jacket.

The engine is started from a store of air compressed to 120 pounds and admitted to the cylinder by a hand starting valve which is shut off as soon as the engine has attained energy of motion sufficient to effect its own compression of the charge. Cylinder heads, piston, piston rod and cylinder covers and stuffing boxes are all water jacketed. The frequency of combustion strokes renders unnecessary the same weight of fly-wheel as is required for four-stroke engines, and a cylinder may be of half the diameter of the single-acting Otto.

The steadiness in running makes these engines particularly suitable for the driving of alternators in parallel.

A twin cylinder engine of 2,000 B. H. P. will run at 75 revolutions per minute and measure 47 feet 6 inches by 41 feet in plan. Figs. 9 and 10 show this engine in internal view, the larger one being of 750 B. H. P. The illustration of the Cargo Fleet Iron Works shows what is at present perhaps the largest single installation of gas engines in Great Britain. These engines are of the Cockerill type and are made by Messrs. Richardson, Westgarth & Co., of Middlesbrough, who make these engines from 250 to 5,000 I. H. P. The work done is the blowing of the blast furnaces whence the gas is derived. The installation of blowing engines consists of seven 800 I. H P. engines. Each engine has a single-acting gas cylinder 51 inches diameter and a blowing cylinder 59 inches diameter by 55-inch stroke, and is designed to run up to 80 revolutions per minute, blowing in ordinary work against 10-pound blast, but capable of blowing up to 16 or 17 pounds with reduced volume, when necessary. Six of the air cylinders are fitted with ordinary circular valves and the seventh engine is fitted with the patent sliding air valves and gear of the Southwark Foundry Company, of Philadelphia, of which the engine makers are sole licensees in the United Kingdom.

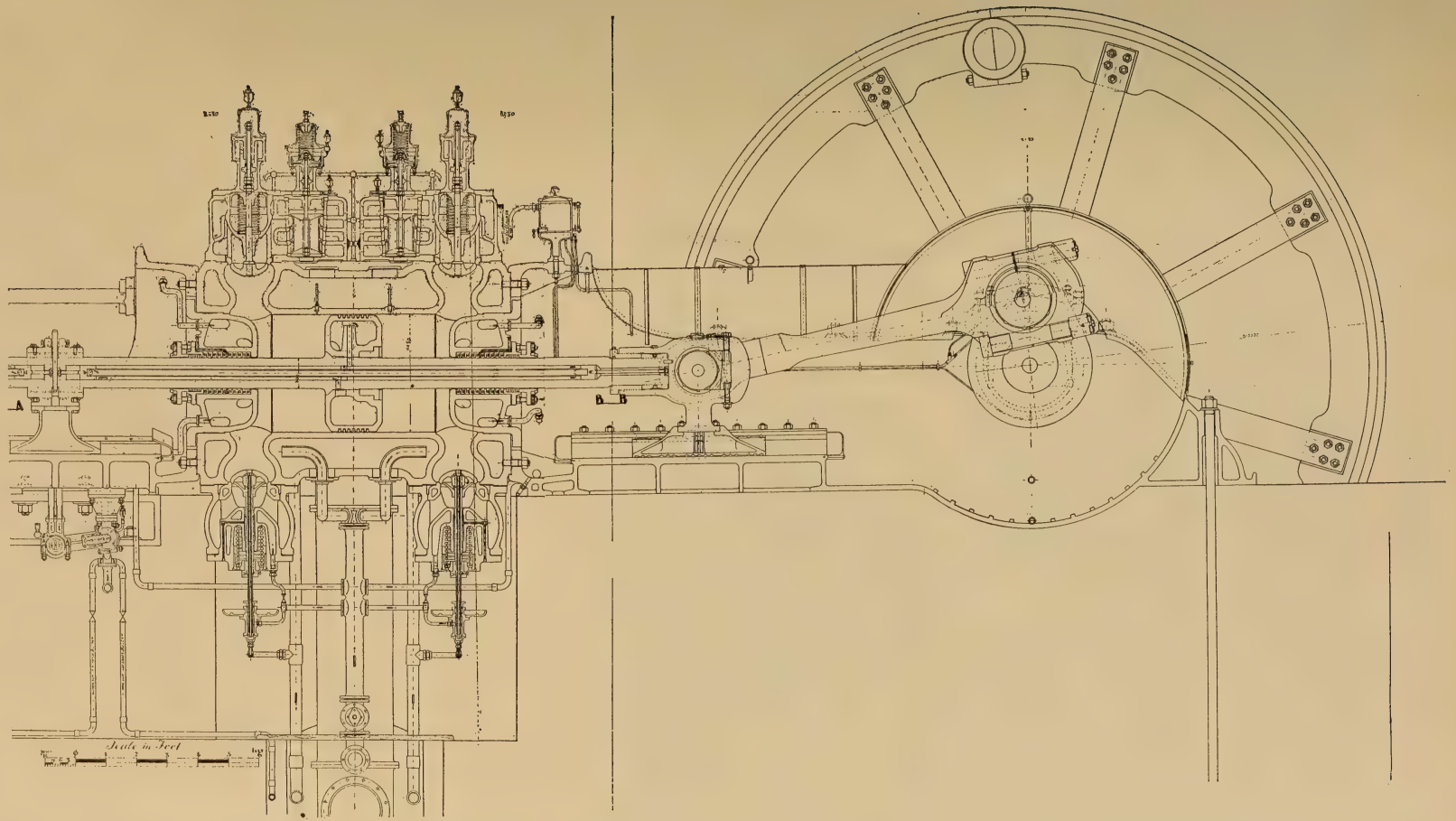
The gas used by the engines is cleaned by passing it through the Theisen patent rotary counter-current gas washer, three of which have been supplied to the works, each capable of dealing with the gas from one blast furnace.

The dynamo engine supplied to the same iron works has tandem double-acting cylinders 23½ inches diameter × 31½-inch stroke, arranged to run at 125 revolutions per minute, and is direct coupled to a 500 E. H. P. continuous-current generator, 240 volts.

Cockerill engines have been supplied to Hong Kong, where an installation of two 1,100 B. H. P. twin tandem double-acting engines have been put down, each engine having four cylinders 25½ inches diameter × 31½-inch stroke arranged to run at 120 revolutions per minute, direct coupled to a continuous-current generator, and two tandem double-acting engines, each having two cylinders 25 inches diameter × 31½-inch stroke, arranged to run at 120 revolutions per minute and direct coupled to continuous-current generator.

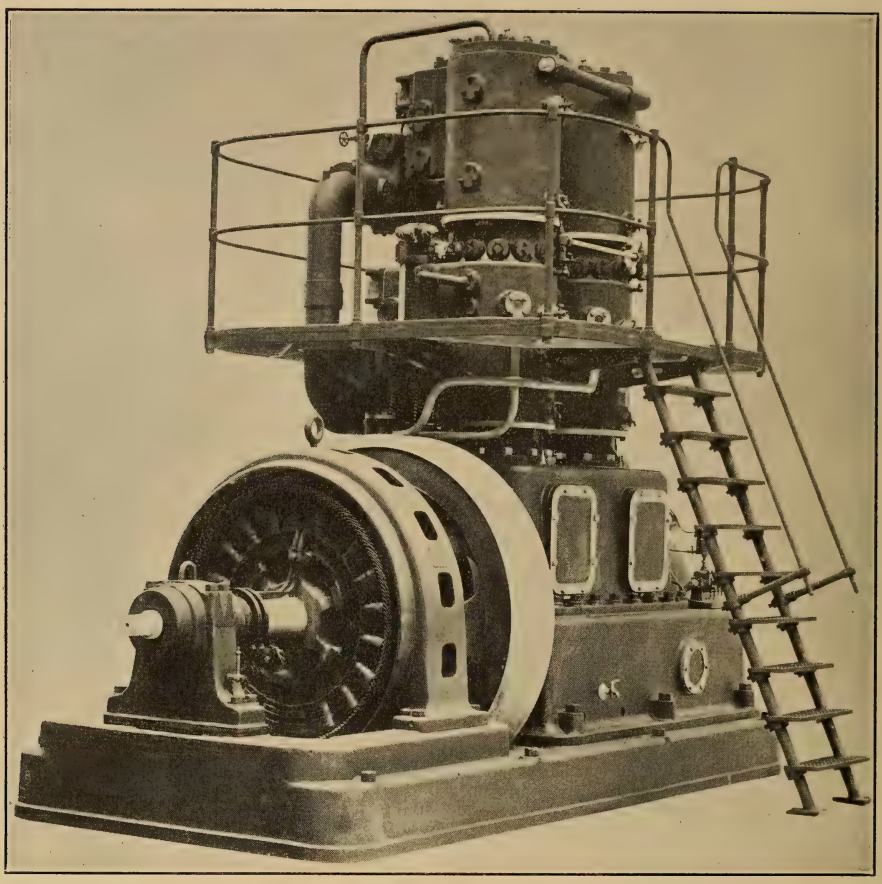
The generators are manufactured by Messrs. Dick, Kerr & Co., of Preston, the larger ones having 12 poles and the smaller ones 10 poles, the machines being compound wound. The producer plant has a total capacity of about 4,000 I. H. P., 3,000 of this being for the engines and the remainder for heating the plate furnaces, etc., in the shipyard, and is supplied by the Power Gas Corporation, London, and consists of three Mond producers with the necessary washing and cleaning plant, etc., complete with coal elevating plant. The above plant is at the shipyard of Messrs. Butterfield & Swires, of Hong Kong.

The Cockerill engine works on the Otto cycle and is made either single or double acting. As with other large gas engines, particular attention is given to the cooling of the cylinder



SECTIONAL VIEW OF 2,000-H. P. TANDEM GAS ENGINE FOR BLAST-FURNACE GAS. BUILT BY MESSRS. EHRHARDT & SEHMER, SCHLEIFMUHLE-SAARBRUCKEW

The illustration shows but one of the two tandem cylinders; both are alike. A photograph of this engine is shown on page 31



WESTINGHOUSE VERTICAL TANDEM SINGLE-ACTING GAS ENGINE. BRITISH WESTINGHOUSE ELECTRIC AND MANUFACTURING CO., MANCHESTER

throughout and all other parts necessary to be cooled, such as the piston and rods, cores, exhaust valves.

In all gas engines it is desirable to retain a constant compression by always admitting the full volume of air, and unless special care were taken this would cause a weak mixture of gas at light loads. In the Cockerill engine this is provided against by varying the gas admission as regards time only. If a small volume of gas has to be admitted, it is admitted at a later period. But in all cases wherever gas admission commences it continues to the end of the admission stroke, so that the mixture is always practically alike in quality but differs in quantity. Certainty of ignition is thus secured, the mixture being constant about the ignition point: about 100 cubic feet per B. H. P. per hour of ordinary blast furnace gas will be consumed. The working of blowing cylinders naturally presents itself as the first particularly appropriate work for a gas engine to perform when fed with blast furnace gas, but the Middlesbrough firm make also engines for dynamo driving, for driving mine ventilating fans, as at Powell Duffryn, and for rolling mill driving. What blast furnace gas requires to enable it to be most fully utilized is a 24 hours' load, and such work as calcium carbide making and other electrolytic industries naturally present themselves as offering a 24 hours' load. In one case of a blowing engine in Italy, a single cylinder

double-acting engine is giving 2,000 I. H. P. Gas engines are thus quite as large as the general run of large steam engines, and can be obtained up to 5,000 horse-power in one unit.

A certain scavenging action is obtained in the Cockerill engine because both exhaust and air admission valves are open at the same time for a short period. The exhaust gases are rushing out with great energy and continue to do so for some time, exerting a pull into the cylinder space and drawing in fresh, clean air to sweep past the igniting plugs and clear out the last of the burnt charge.

While constant compression is usually employed for electrical work, it is sometimes desirable to employ variable compression where blowing engines have to be driven, especially where speeds are slow and absolutely regular running is not so important as for electrical work for which constant compression is employed.

The amount of water required should be such that its temperature when leaving the engine should not exceed 50 degrees C. = 122 degrees F. This is secured by supplying about 9 gallons per brake horse-power per hour at an initial temperature of not more than 59 degrees F. which, if exceeded, demands more water.

The blowing engine of the Cockerill Company is well shown in the photograph. This is a double-acting engine with the blowing tube in tandem on the same rod. The working cylinder has a diameter of 1,100 mm. and the same stroke, and the engine runs at 80 revolutions per minute.

It may be added that the Cockerill Company were the first on the Continent to realize the value of Thwaite's invention, and they built a trial gas engine soon after Thwaite had published his suggestions in the *Iron and Coal Trades Review* and in *Le Figaro*, and had the same attention been paid by British ironmasters there would ere this have been as many makers of large gas engines in Great Britain as in Germany, but the use of blast furnace gas has been unaccountably shirked by the ironmasters of Great Britain owing, probably, to the possession of so many natural advantages that they can afford to neglect economies of which the foreigner is glad to avail himself. Others, however, tell us that the British ironmaster is so heavily mulcted in royalties that there is nothing left available for plant improvement.

THE SUCTION GAS PRODUCER

By F. J. Rowan, Assoc. M. Inst. C. E., M. I. E. S.

THERE are few industries in Britain which have made more rapid progress than that of suction gas producer plant. The way was undoubtedly prepared for it by previous experience with pressure producers, extending over many years; nevertheless, the idea put forward in 1894 by Bénier, of Paris, possessed considerable originality, and has resulted in simplifying gas power plant to such an extent that for moderate amounts of power, up to about 200 brake-horse-power, it possesses advantages over steam from the point of view of cost and convenience of installation, whilst the fuel-costs enable suction plants to compare favourably with gas engines using illuminating gas from town gas mains. For the larger amounts of power, say from 150 horse-power and upwards, the cost of town gas becomes prohibitive for economical working, and the cost of anthracite, or even coke of good quality, may seriously handicap the suction plant as against the pressure producer plant using bituminous coal.

Bénier's plant was introduced into Britain in 1896, but in its original form was found to be unsatisfactory, and improvements were made by Taylor, also of Paris, who devised a more serviceable producer with external vapourizer. Several of the Bénier-Taylor plants were erected in Britain through Messrs. W. C. Horne & Sons, of London, and worked successfully. Almost simultaneously with Bénier's attempt, Messrs. Körting, in Germany, carried out some experiments with the object of supplying recuperation of heat, or the regenerative principle, as it is called, to producer practice, and had advanced far enough to formulate a patent for their plan in July, 1895. Nothing, however, came of this effort, as additional experimenting revealed defects in the suction system as thus arranged which the inventors considered to be insuperable. The next advance was effected in 1901 by Julius Pintsch, of Berlin, who made a successful installation of suction gas plant in Belgium, and by Dr. F. H. Bowman, of Manchester, who, with his son, Mr. F. E. Bowman, made a producer in March, 1901, and exhibited it at work in Manchester in August of that year. The first plant on this latter system, called the "Dynamic," to drive an engineering shop was put down in June, 1902, and was of 30 brake-horse-power, the tests on full load showing a fuel consumption of 0.76 pound of anthracite per brake-horse-power-hour, including fuel used for banking. This plant was exhibited at the Royal Agricultural Society's show in London in that month. In July, 1902, a Bowman producer was installed at Altrincham Sewage Works to drive two Crossley engines of 25 brake-horse-power each for pumping sewage; and in September of the same year a larger one, of 150 brake-horse-power, was erected at the Trafford Park Works of the British Westinghouse Company, to drive a three-cylinder vertical, enclosed-type gas engine.

In 1901 Messrs. Crossley Bros. ex-

hibited a suction gas plant at Cardiff; Messrs. Newton Bros., of Derby, also state that they had a suction producer at work in that year; and, commencing about 1903, designs by Dowson, Tangye, Andrews (now Hornsby), Campbell, National Company, and many others have been brought forward.

Commencing with such small beginnings at such a comparatively recent date, it is remarkable that there are now some twenty-five British designs on the market and about twenty firms engaged in the business, several hundreds of installations being now in more or less successful operation, and the present rate of manufacturers of new plants is about 200 to 300 per annum.

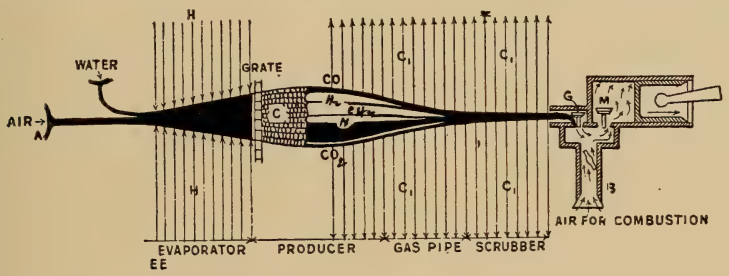


FIG. 1.—PROF. DALBY'S DIAGRAM OF SUCTION-PRODUCER ACTION

PRINCIPLES OF SUCTION GAS PLANT

The excellence and desirability of the gas engine as a prime mover having been established, the two main principles which have operated in the production of this modern form of apparatus for the supply of gas fuel are, first, the desire for simplification of producer plant, and second, the effort to obtain economy of heat.

1. The suction system abolishes at one stroke the separate boiler for steam raising, with its attendant expenditure of fuel, and the gas holder, both of which are necessary in the ordinary pressure producer system. That of itself is so great a step in the simplification of the plant that it offered a powerful inducement to designers and experimenters to persevere in their efforts to attain this result. In addition to the fact that storage of gas is unnecessary, in the suction system the fuel in the producer is consumed, and gas is produced only as it is required by the engine, which itself governs the rate of gas production. Consequently a much smaller quantity of gas requires treatment, and the cooling and cleaning apparatus is reduced to a minimum. The suction producer being worked more slowly, and the proportions of air and steam admitted being under control, there is no excessive heat in the producer, and consequently less trouble is experienced in connection with poking and clinkering operations. The sum of improvement under this head is, therefore, considerable.

2. It is not necessary here to enter into the elements of thermochemical calculations connected with the production of gas. They are many and complex, and are the same for all gas producers, but at best express only theoretical possibilities under conditions which are rarely realized. Here we are concerned with practical results, and in this light the diagrams published by Prof. Dalby, in his paper read before the British Association at York, are eminently useful towards affording an insight into the heat problems connected with suction producers.

Fig. 1 gives a diagrammatic representation of the actions taking place in a suction producer plant, the course of the air and gases being arranged as nearly as possible in a straight line. The air for combustion enters at *A*, being joined by the water vapour before entering the

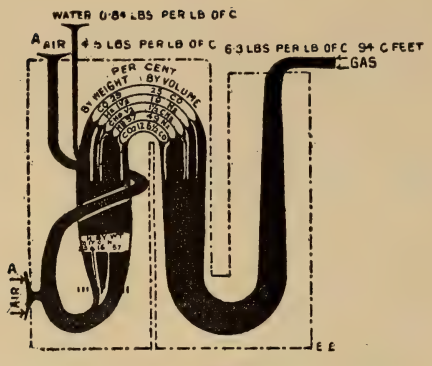


FIG. 2.—DALBY'S DIAGRAM OF HEAT TRANSFER

combustion zone of the producer. Both air and water must receive heat in the preliminary stage of their passage to fit them for their work in the producer. Heating the air increases its capacity to absorb moisture, besides facilitating combustion, and, of course, the water must be vapourized. That action is represented by the arrows pointing inwards in the region marked *H*. The air and steam mixture passes through the producer grate, and here the fuel (anthracite or coke), air and steam react on one another and produce a gaseous mixture, the proportions of which an ordinary analysis will express, and which is represented by the horizontal lines of different thicknesses passing to the right from *C*. The density of the gas in this state is small, and if it were taken direct into the engine cylinder a charge of only small energy value would be obtained. It is, therefore, necessary to cool the gas down to nearly atmospheric temperature during its passage through the region marked C_1, C_1, which embraces the gas pipe (or downcomer) from the producer, the scrubber, and the expansion box or chamber usually placed close to the engine. Heat must, therefore, be abstracted from the gas in the outgoing portion of the plant, and this is represented by the arrows pointing outward in the region C_1, C_1. It follows easily from this representation that the recuperative principle demands that the heat which is rejected at *C* should be transferred as fully as possible to the region at *H*, and it is on this point that the excellence of different designs, from the point of view of heat economy, to a great extent depends.

Figs. 2 and 3 illustrate methods in which the transference of heat is carried out. In Fig. 2 the air and water streams are shown coiled once round the producer body to denote that the heat required by them is derived entirely from that portion of the apparatus. The evaporator or vapourizer is almost always fixed in some part of the producer, and in some cases radiation from the hot lining is also utilized to heat the mixture of air and steam. In Fig. 3 this heat transfer is further developed, the streams of air and water being shown as deriving heat from the hot gas escaping by the branch and downcomer from the producer, in addition to the heat abstracted from the producer.

Both of these methods are applied in greater or less degree in the British suction producer plants, but it would be foolish to conclude that finality has been reached in this direction. For instance, it will be noticed that neither of the methods makes any attempt to utilize the heat which is abstracted from the gases in the scrubber section of the plant. If it should be found difficult to recover heat from that portion with-

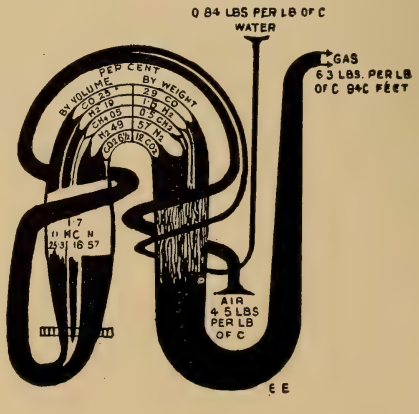


FIG. 3.—DALBY'S HEAT-TRANSFER DIAGRAM

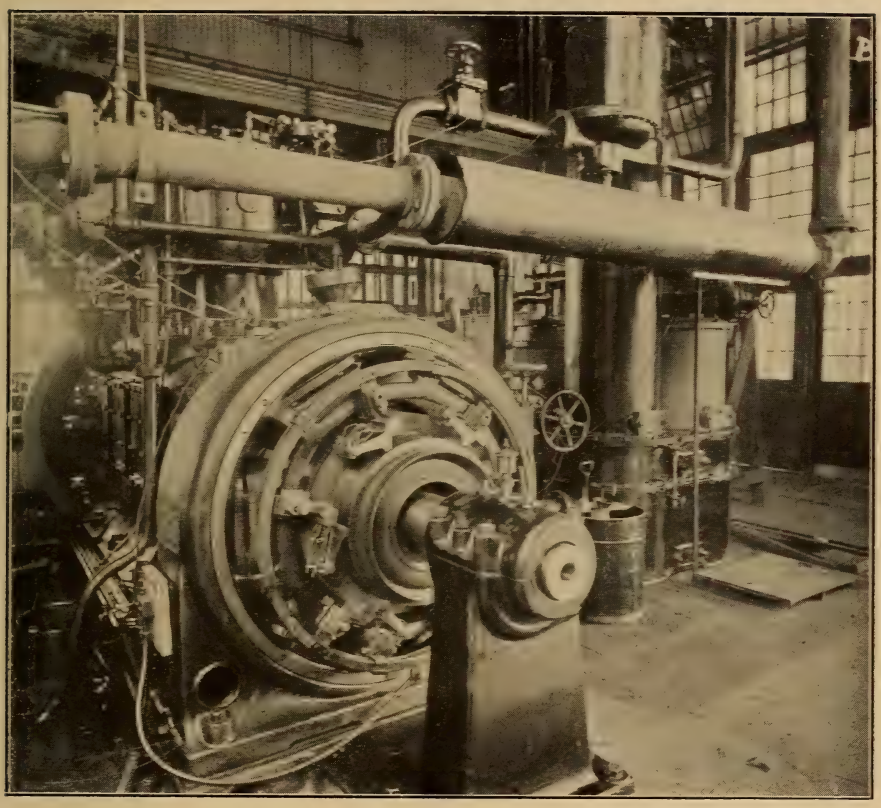


FIG. 4.—DYNAMIC SUCTION GAS PRODUCER AS INSTALLED AT BRITISH WESTINGHOUSE CO., MANCHESTER, DRIVING 130 H. P. THREE-CYLINDER WESTINGHOUSE GAS ENGINE

out unduly complicating the apparatus, this points to the necessity for a more thorough abstraction of the sensible heat of the producer gases on their way from the producer to the scrubber. And there remains the enormous waste of heat in the exhaust gases and jacket water of the engine as a promising field for further recuperation or economy of heat.

The questions of air and water regulation are closely connected with this branch of the subject—although they also belong to the details of construction of the different designs—because they exert a controlling effect upon the temperature found in the producer, and, therefore, upon the quality and temperature of the gas made, and so react on the whole system of plant.

The effect of working producers with air alone is well known to be a high temperature of combustion, increasing the formation of clinker, with attendant difficulty of working and heavier amount of wear on the producer, and a lessened heat economy in the whole operation of producing and using the gas. If producers were worked constantly at full load, or at one fixed load, the regulation of air and steam would be easy, because the supply of the proper quantities once set, no further change would be necessary. Variation of load, and consequent fluctuation of the draught of air through the producer, must, however, be provided for, and it is here that ingenuity and fertility of resource have play. It is quite well understood that if an engine passes from a heavy load to a light load, or vice-versa, and there is no regulation of the amount of

steam, troubles will be encountered at both the engine and the producer ends of the plant, in consequence of fluctuations in the quality of the gas and in the temperature of the producer. To meet this state of affairs clever devices have been introduced with great success, notwithstanding the variety of conditions to be dealt with. There is great diversity in the designs of vapourizers employed in suction producer plant. Sometimes the vapourizer is internal, sometimes external to the producer, sometimes partly one and partly the other. "In some cases it takes the form of an open-mouthed boiler, made either of cast iron or of steel; sometimes a coiled pipe is used; or again the vapourizer is merely a heated surface over which the water trickles." It will readily be understood that the water may be present in these various forms of apparatus in bulk, or supplied in successive drips, or allowed to trickle. It has been pointed out that there are three methods of automatically regulating the water (and that is, of course, by steam) supply, viz.:

1.—By adjusting the amount of water sucked in.

2.—By adjusting the amount of a secondary (dry) air supply, thus reducing the proportion of water vapour introduced into the furnace.

3.—By varying the temperature of the air supply which quickly changes its water vapour-carrying capacity.*

All these methods have been drawn upon, the mechanical devices employed in carrying them out being, as a rule, actuated by the sucking action of the engine in drawing in

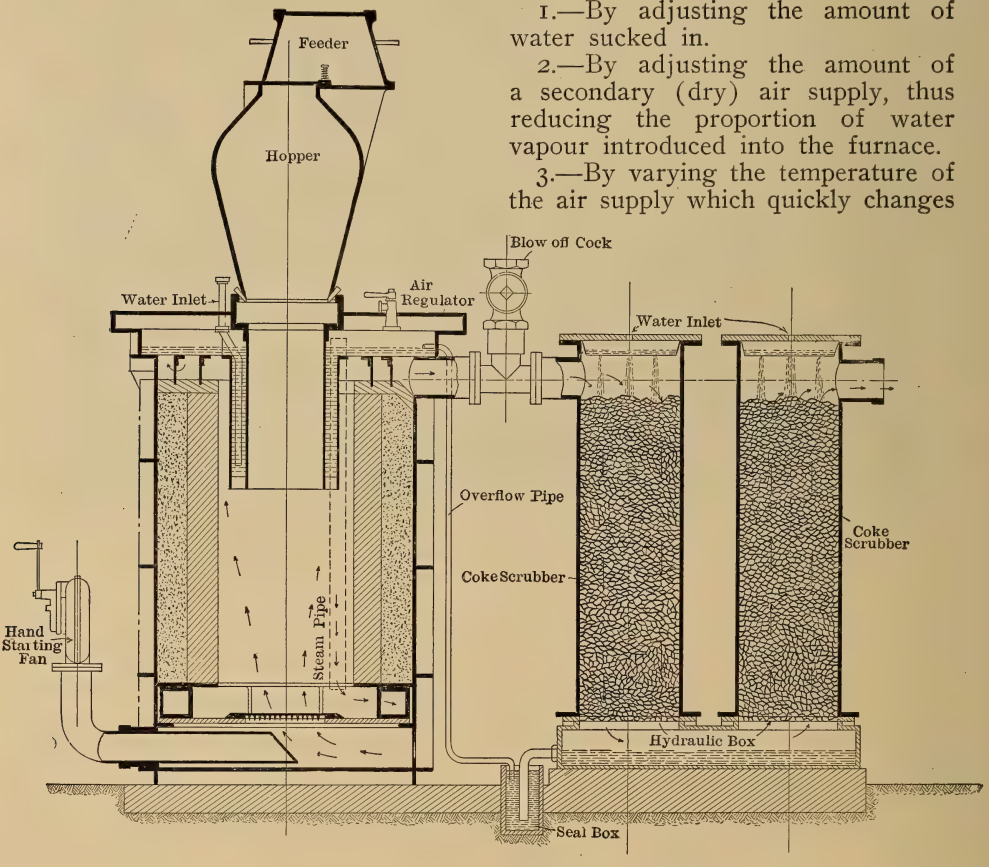


FIG. 5.—SECTIONAL VIEW OF THE CROSSLEY PRODUCER

* German experiments seem to indicate that the suitable temperatures for moisture-laden air are from 52 to 76 degrees C. Above 76 degrees C. too much moisture is carried into the producer. Gasmotorentechnik 6, pp. 154-158, January, 1907. (See Science Abstracts, March, 1907.)

FIG. 6.—SUCTION GAS PLANT MADE BY MESSRS. CROSSLEY BROS., LTD., MANCHESTER, FOR USE WITH GAS ENGINES IN SIZES FROM 5 TO 600 B. H. P.

charges. Different makers, of course, have preferences for different devices; but, after all, there is force in the opinion given by Mr. Hugh Campbell (Trans. Inst. of Engineers & Shipbuilders, Vol. L., Part 4), as the result of considerable experience in the operation—as well as construction—of suction gas plants, to the effect that, in practical work the periods of light load are either too short or so infrequent that the necessity for regulating devices is rarely felt, if the gas plant is worked with a fair amount of intelligence.

ELEMENTS OF CONSTRUCTION

Some of these have necessarily been indicated already, but the question of dimensions and areas is one of the most important connected with the subject. The area of fire grate, or diameter of the fire, naturally suggests itself as a point of primary importance; but it is not easy to arrive at any rule for this dimension on account of a multiplicity of conditions, some of them apparently antagonistic, being involved. To provide for a light load it would at first sight appear that a restricted area is required in order to secure a sufficient velocity of air* current through the fire at diminished pressure, due to the action of the engine. But sufficient area for the entry of the air between the fire bars must be allowed; and, moreover, the proper size of pieces of fuel being comparatively small, the diameter must not be such as to cause any hanging of the mass of fuel in its downward movement. Some accumulation of ashes must also be allowed for without choking up the air openings. The diameter has an influence upon the height of fire, and here questions of the resistance of the column of fuel to the

* See some remarks on this point by Mr. R. J. Willcox, in Trans. Inst. Engineers and Shipbuilders in Scotland. Vol. L., Part 4, page 6.

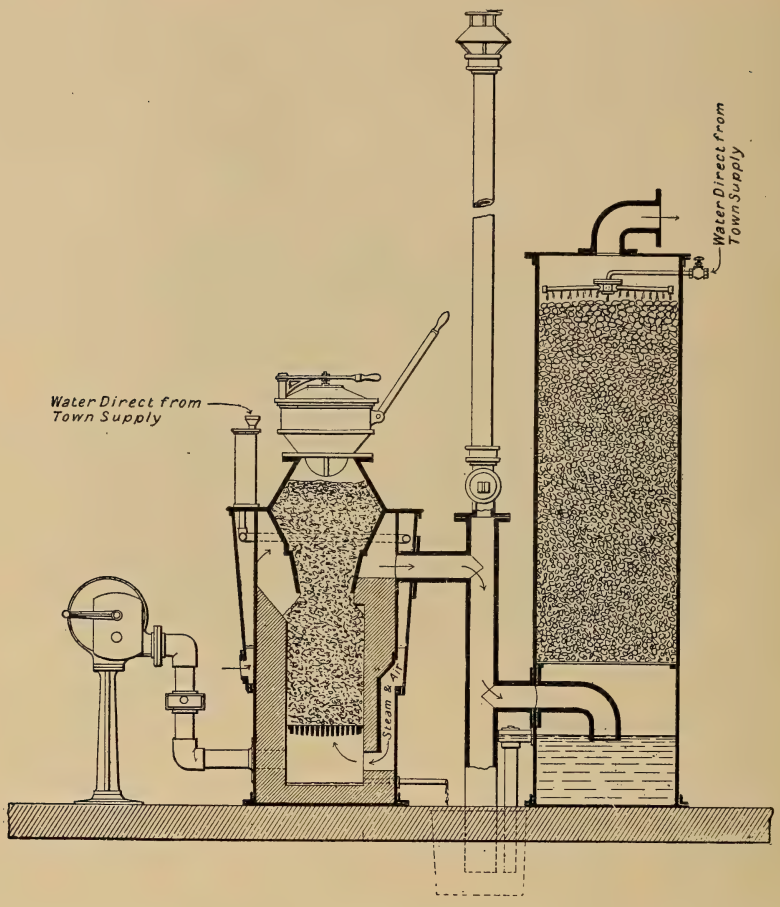


FIG. 7.—SECTIONAL VIEW OF DOWSON SUCTION PLANT

air currents, and its effect on the velocity of air and gases, and consequently on the fire temperature and composition of the gas, come in for consideration. It would seem that a suitable size has in the first place been determined by experiment or a system of trial and error. The engine cylinder supplying the moving force—and acting as the pulse—of the whole system, we are naturally led to it as a governing factor.

Mr. W. A. Tookey remarks, in an interesting paper on "Suction Gas Producers" (Trans. Junior Inst. of Engineers, Vol. XVI.), that "experience has shown that the diameter of the fire at its base—or combination zone—is best expressed as a function of the piston's area and displacement. M. Rudolphe Mathot states that his experience shows that best results are obtained when the cross-sectional area of the fire is from 0.5 to 0.9 times the surface of the piston, and even from 0.25 to 0.5 times, according to the nature and size of the fuel. Dr. Nagel, in an article in CASSIER'S MAGAZINE, gives the area of fuel at the grate bars as from 0.08 to 0.1 square feet for every 10 horse-power. Directly expressed, the British practice seems to be that a 50 brake-horse-power gas engine having a piston of about 15 inches diameter, a displacement of 2.25 cubic feet, and mean piston speed of about 600 feet per minute, shall draw from a producer of about 15 inches diameter fuel base. M. Mathot's

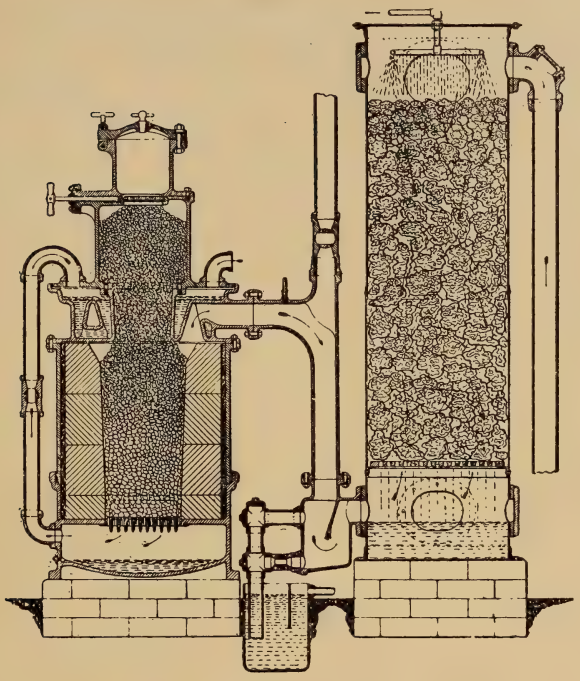


FIG. 8.—SECTION OF TANGYE GAS PRODUCER

measurement would vary from 7½ to 10½ inches and 14½ inches diameter. Dr. Nagel would provide only from 8½ to 9½ inches diameter."

Regarding the depth of the fire, it is stated that "a common depth of incandescent fuel is 20 to 24 inches, while in the smaller producers 15 to 18 inches is allowed when anthracite beans or small nuts are burnt." When the generating chamber has become well heated and a constant quality of gas is being given off, it is found that the production of satisfactory gas continues even when the fire has been allowed to sink to from 9 to 12 inches thick, or even less when engines are lightly loaded, but with such thin fires no fresh fuel can be added without disturbing the whole temperature conditions of the generator.

Until the appearance of the reports of trials of suction gas producer plants at the Glasgow show of the Highland and Agricultural Society of Scotland in 1905, and at the Derby show of the Royal Agricultural Society of England in 1906, little information could be gathered about producer sizes and capacities. We find Professor Dalby saying, in his paper on "Suction Gas Plants," read before Section G, of the British Association, at York, "At the present time there does not appear to be a definite relation between the proportions of the furnace of the producer and the power to be produced. The incandescent part of the fuel occupies the vertical space between the level of the grate and the bottom of the inverted cone which guides the fuel down from the hopper to the fire, and the height of this space, which is the thickness of incandescent fuel through which the air and steam are drawn, is about 2 feet in the case of producers designed for engines of from 15 to 20 horse-power. The area of the cross section of the furnace averages about 0.065 to 0.075 square feet per brake-horse-power. The capacity of the

furnace, reckoned as the cubic contents of the space between the fire-bars and the bottom of the distributing and distilling cone, is 2.37 cubic feet in the case of the 20 horse-power producer of the National Company. In the Crossley design the capacity is 1.58 cubic feet for 15 brake-horse-power. These figures reduce to 0.118 cubic feet and 0.105 cubic feet per brake-horse-power, respectively. The diameter of the furnace in the National design is 15½ inches for a 20 horse-power furnace, and in the Crossley design 12 inches for a 15 horse-power furnace, giving actual areas of 1.31 square feet and over 0.785 square feet, respectively. The depth of the fire in the case of the National design is 1 foot 10 inches, and in the case of the Crossley producer 2 feet."

From the information given in the judges' report of the trials at the Glasgow show, Mr. Tookey has compiled the following table, calculating the total weight of anthracite as 58 pounds per cubic foot:

The judges remarked on the discrepancy between the fuel consumption per brake-horse-power-hour at full load and that at half load. In the case of the Campbell Gas Engine Company's plants, "the coal consumption per brake-horse-power per hour is less on the half load than on the full load trial. This is obviously the opposite from what should be the case, and it may be due to the fact that the fires in the producers in these two plants were not lighted until the morning of the first test, whereas the other plants had their producers in working order the night previously. This would naturally mean that a quantity of fuel was expended in heating up the walls of the producer."

In the opposite table an attempt has been made to give a general view of British designs by classification of their main features. Naturally, a good many constructive details of some importance could not find a place in such a table, and, of course, it would be hopeless to attempt to judge the comparative merits of the various designs by the information which the table conveys. Inspection of examples or drawings would be required for that, with some knowledge or experience of the performance of the plans so compared. A general idea may, however, be obtained of the leading features of British designs. The variety in design and arrangement of the vapour-izer is well marked; but charging hoppers with double valves or slides, charged by hand, are the rule, there being only five or six instances of some form of automatic feeder entering into the design. The general practice is also to keep the storage

GENERATOR CAPACITIES AND FUEL CONSUMPTION

Maker.	A Lbs.	20 B.H.P. Plants. Full Load. R.	20 B.H.P. Plants. Full Load. C.	20 B.H.P. Plants. Half Load. R.	20 B.H.P. Plants. Half Load. D.	8 B.H.P. Plants. Full Load. R.	8 B.H.P. Plants. Full Load. C.	8 B.H.P. Plants. Half Load. R.	8 B.H.P. Plants. Half Load. D.
Campbell	242	13.5	0.8	9.35	0.65	12.5	1.05	8.45	0.67
Crossley	250	13.2	0.65	8.4	0.655	....	....	....	....
National (Dowson)	340	12.0	0.65	7.15	0.68	10.9	0.692	7.0	0.70
Tangye	157	31.5	0.705	18.1	0.795	20.4	0.92	13.4	0.9

In the above, A = Pounds of anthracite at 58 pounds per cubic foot.
C = Consumption of coal per hour per I.H.P. on full load trial.
D = Consumption of coal per hour per I.H.P. on half load trial.
$R = \text{Ratio of } \frac{PE}{G}$.
P = Piston displacement in cubic feet.
E = Average number of explosions per minute on trials.
G = Generator capacity in cubic feet.

GENERAL CLASSIFICATION OF FEATURES OF BRITISH PRODUCER DESIGNS.

Name.	Vaporizer.	Hopper.	Bell.	Ashpit.	Grate Bars.	Air Heater.	Fan.
Dynamic	V V_2	H	B_1	Ad Ac	Gs	R_5	Fb
Crossley	V V_3	H	B	Ad Ac	Gh	R	Fb
Dowson	V_1	H	B	Aw Ac	Gh	R_2	Fb
Tangye	V	H	B	Aw Ac	Gh	R	Fb
Hornsby	V	H	B_1	Aw Ac	Gh	R	Fb
Campbell	V	H	B	Ad Ac	Gh	R R_4	Fb
Fielding	V_6	H	B	Ad Ac	Gr	R_1	Fb
National	V_3 V_5	H	B	Aw Ac	Gh	R R_3	Fb
Mason	V_1	H_2	B	Aw Ac	Gh	—	Fb
Davey-Paxman	V_1	H	B	Ad Ac	Gh Gs	R	Fb
Kynoch	V_4	H	B	Ad Ac	Gh	R_3	Fb
Griffin	V_3	H_2	B_1	Aw Ac	Gh	R	Fb
Newton	V_5	H_1	B	Ad Ac	Gh	R_2 R_3	Fb
Mersey	Vc	H_1 H_2	B	Ad Ac	Gv	R_2 R_3	Fb
Dudbridge	V_4	H	B	Aw Ac	Gh	R_1 R_3	Fb
Hindley	V V_3	H	B	Aw Ac	Gh	R R_3	Fb
Industrial	Vc V_4	H_2	B	Ad Ac	Ga	R_2 R_3	Fe
Acme	V	H	B_1	Aw Ac	Gh	R	Fb
Drake & Gorham	V V_4 V_5	H	B	Ad Ac	Gh	R R_3	Fb
Watt	V_5	H_2	B_1	Ad Ac	Gh	R_2	Fb
Stewart	V_4	H	B	Ad Ac	Ga	R_3	Fb
Butler	V V_1	H_2	B	Aw Ac	Gs	R R_2	Fe
Daniels	V V_2 V_4	H	B	Aw Ac	Gh	R	Fb
Paywell	Vc V_4	H	B	Ad Ac	Gh	R_3	Fb
Brotherhood	V	H_1	B	Ad Ac	Gh	R	Fb

In the above, V = Vaporizer on top of reducer.
V_1 = Vaporizer on sides of producer.
V_2 = Vaporizer below fire in producer.
V_3 = Vaporizer forming sides of storage or coking bell.
V_4 = Vaporizer surrounding branch or downcomer pipe.
V_5 = Vaporizer inserted in branch or downcomer pipe
V_6 = Drip vaporizer.
Vc = Coil vaporizer.
Vs = Special vaporizer in double casing of producer.

In the above, H = Charging hopper with double valves or slides.
H_1 = Charging hopper with single valve or slide.
H_2 = Charging hopper with automatic feeder.

In the above, B = Storage or coking bell to govern height of fuel.
B_1 = Storage or coking bell used merely as extension of hopper.

Aw = Ashpit wet.
Ad = Ashpit dry.
Ac = Ashpit closed.
Ao = Ashpit open.

Gh = Grate bars horizontal.
Gv = Grate bars vertical.
Gr = Grate bars revolving.
Gs = Grate bars special (shaking, etc.).
Ga = Grate bars absent.

In the above, R = Air heated by passing over surface of water in vaporizer.
R_1 = Air heated by passing over heating surface at producer top.
R_2 = Air heated by double casing of producer body.
R_3 = Air heated by passing over surface of downcomer pipe.
R_4 = Air heated by passing through pipe inserted in gas in downcomer pipe.
R_5 = Air heated by surrounding exhaust pipe of engine.

Fb = Blowing fan.
Fe = Exhausting fan.

or coking bell full, so that the height of the fire is maintained constant, and to have a closed ashpit, although practice is pretty well divided between dry and wet ashpits. The majority of designs use horizontal grate bars in some form, and all but one or two use blowing fans. The variety in plans for heating the air naturally bears some relation to the diversity of vapourizer designs, as these two parts of the apparatus are

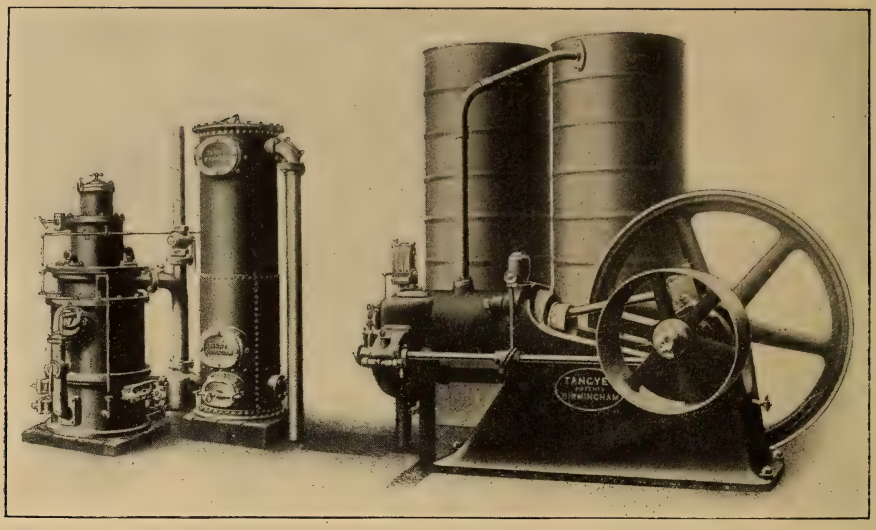


FIG 9.—TANGYE SUCTION PRODUCER PLANT AND GAS ENGINE

necessarily to some extent combined. Arrangements for clinkering and poking are not dealt with in the table, nor do the other parts of the plant enter into it. There is, however, some variety in these and other details which plans of the different designs may disclose.

ILLUSTRATIONS OF DESIGNS

To illustrate all the modifications of British suction gas plants in use would require a large amount of space, as most of the makers construct their plants in different sizes, those of larger capacity not being mere enlargements of the smaller design. In the following we give illustrations of some of the principal makers' designs—in the order of the preceding table—to show the variety of British manufactures.

Fig. 4 shows, in elevation, the Dynamic Gas Company's plant as now made for small sizes, this plant having been originally supplied to the British Westinghouse Company's works at Trafford Park, Manchester. For larger sizes and continuous running, the generator, cooler (which is the downpipe from producer) and scrubber all stand on a water seal, so that they can be cleaned out while running. Water is sprayed into the downpipe, as well as into the scrubber; but there is no coke in the downpipe, and dust is washed out of the gas. Dr. Bowman says that they have put down producers ranging from 10 to 250 brake-horse-power, some of the larger sizes on constant load having shown a fuel consumption of 0.6 pound per brake-horse-power, and that suction plants can be made up to 500 brake-horse-power in one unit.

Fig. 5 shows Messrs. Crossley Bros.' suction plant in section, and Fig. 6 in elevation with the expansion box beyond the coke scrubbers. In the designs submitted to test at the Derby show the scrubber was a single cylindrical chamber having two compartments in its height, the upper one being filled with sawdust. The storage bell forms the boiler or vapourizer, and on the grate level there are two cast-iron segmental boxes used as superheaters. The proportion of steam is regulated by cocks in the air space and by the use of a secondary air supply. Messrs. Crossley state that their standard design is made for use with engines of 5 to 600 brake-horse-power, and that plant representing nearly 100,000 brake-horse-power is in use or under construction.

Fig. 7 is a section of the Dowson Economic Gas & Power Company's plant. The vapourizer forms a double casing round the upper part of the producer body, and contains pieces of broken refractory material upon which the water is allowed to drip. A small chamber placed above the producer top receives the water from the supply pipe, and, being furnished with an internal overflow pipe, maintains a constant water level. The water is led into the circular pipe shown in the top portion of the vapourizer, which has a number of nipples pointing downwards, the water being induced to drop out of these in quantity proportionate to the degree of suction. Air is also admitted to the double casing, and passing through the interstices of the broken porous contents takes up vapour and is led to the ashpit by a passage within the outer casing of the producer. It is said that Dowson suction producer plants are in operation representing about 50,000 horse-power.

Section and elevation of the Tangye suction plant are shown in Figs. 8 and 9. The producer casing is of cast iron, with a lining or cushion of sand between it and the fire-brick forming the interior of the producer. The vapourizer is a cast-iron evaporator or boiler of the "open-mouthed" kind placed on top of the producer and exposing a considerable amount of surface to the hot gases on their way to the exit pipe. It is kept nearly full of water, the overflow escaping to the ashpit, where by the heat from radiation and hot ashes an additional quantity of vapour is formed. A regulating water seal is formed at the lower end of the downcomer pipe. There are two branches leading into the water seal, and by closing the cock in the lower of these branches, the water from the scrubber accumulates until it reaches the upper branch, thus immersing the bottom edge of the projecting diaphragm and preventing escape of gas when the plant is shut down.

Fig. 10 shows the Hornsby-Stockport plant in section. The producer casing is formed of riveted plating, with a cast-iron "open-mouthed" boiler or vapourizer on top, carrying the hopper and conical extension, which, however, is not used to regulate the height of fuel in the producer. The water fed into the va-

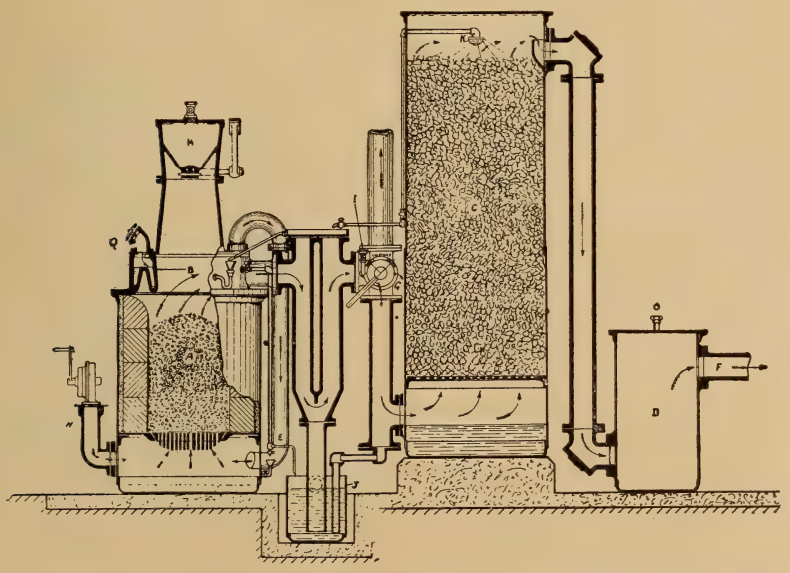


FIG. 10.—THE HORNSBY-STOCKPORT GAS PRODUCER. RICHARD HORNSBY & SONS, LTD., GRANTHAM

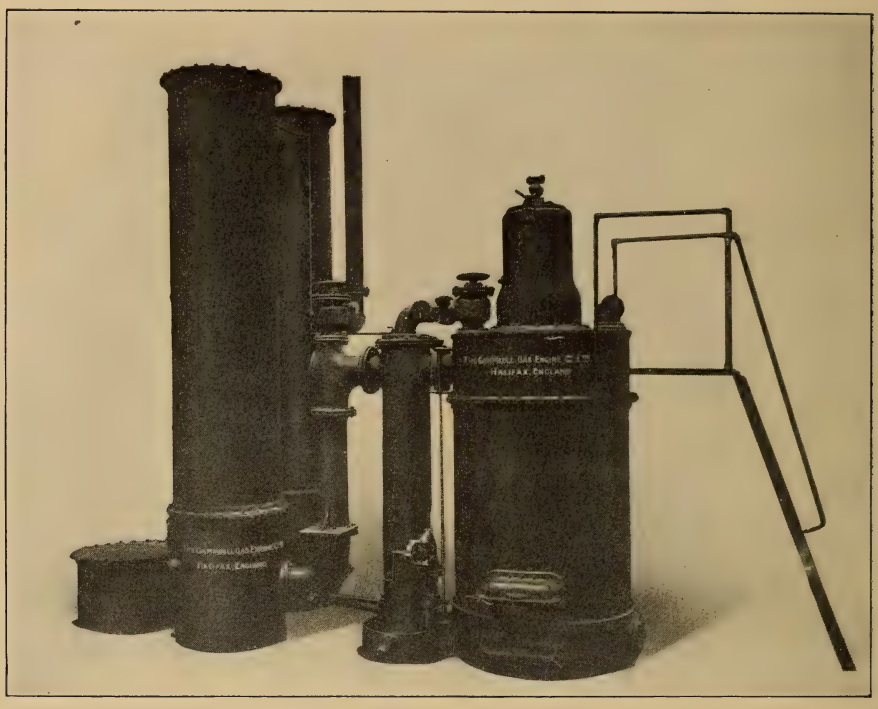


FIG. 11.—SUCTION PRODUCER PLANT BY THE CAMPBELL GAS-ENGINE CO., LTD., HALIFAX, ENGLAND

pourizer is partially heated by flowing through a tray or box placed on the top of the downcomer pipe, which is of peculiar shape.

Figs. 11 and 12 show elevations of the plant of the Campbell Gas Engine Company in the arrangement used for 4 to 40 horse-power and for 90 to 250 horse-power, respectively. The base of both producer and scrubber (or "purifier") is made of cast iron in order to withstand corroding forces; the producer shell is of steel plate riveted, and the boiler or vapourizer forming the producer top is of cast iron, corrugated on its lower surface to provide a passage for the hot gases. In the case of the larger size the purifier is doubled, and the downcomer is utilized to heat the water for the vapourizer by means of a pipe or division placed in the centre of it. Commencing to make these plants in 1904, Messrs. Campbell have turned out about 130 plants, of various sizes up to 250 horse-power, in about two and one-half years, and have now about 800 workmen employed. Extensions are in progress which will raise this

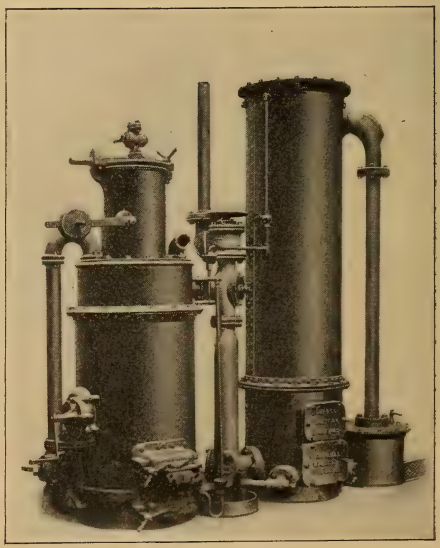


FIG. 12.—SUCTION PRODUCER BY THE CAMPBELL GAS-ENGINE CO., HALIFAX, ENGLAND

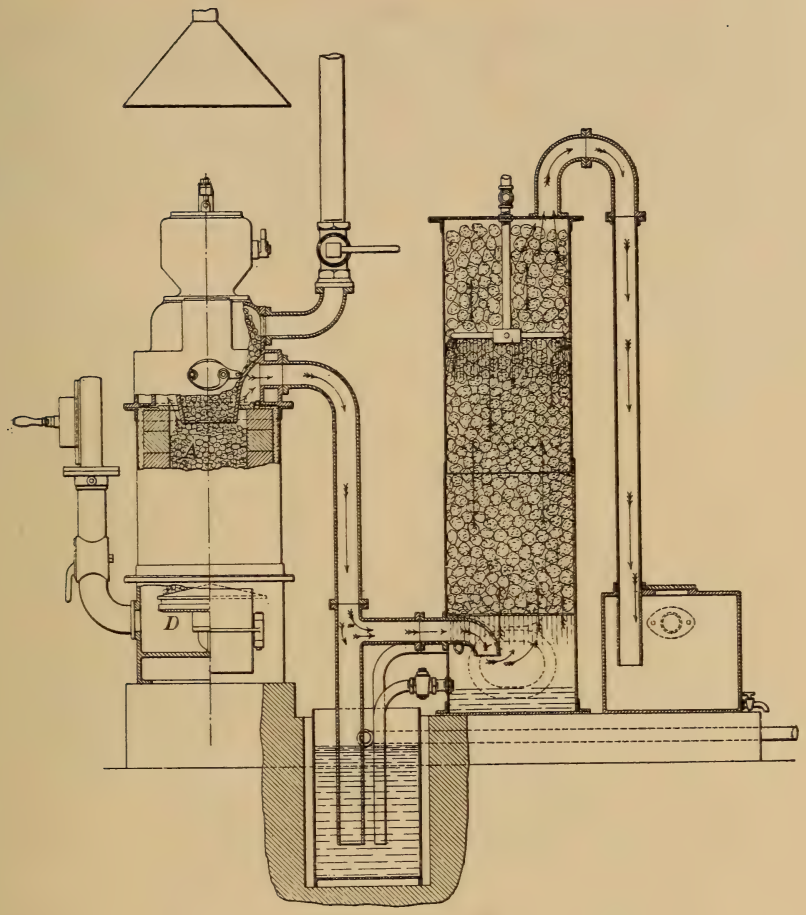


FIG. 13.—SUCTION GAS PRODUCER BY FIELDING & PLATT, LTD., GLOUCESTER, ENGLAND

number to one thousand workmen.

In Fig. 13 is shown a section of the producer plant made by Messrs. Fielding & Platt, Ltd., the notable features of which are found in the arrangements for water supply and for air heating. The air first passes round an iron belt or box formed in the sides of the distributing-bell casting forming the producer top and then to the ashpit by a side pipe into which water is led by a drip pipe near the bottom. Should there be no suction, the water runs off by an escape pipe, but where a suction stroke is made some of the water is carried along with the heated air and passes to the centre of the revolving grate table. The air and water spray or vapour pass out between ribs to the periphery of the circular table or grate, where they escape by the edge to the fuel, having been superheated on their passage. The revolving grate table carries projecting studs to break up the fuel or clinker when rotated. In the scrubber there is an upper compartment above the water spray filled with dry coke, for the purpose of drying the gas, as in the instances in which sawdust is used.

The National Gas Company's plant is shown in section in Fig. 14. The water is first heated in a "Perkins" or "Field" form of tube inserted in the centre of the downcomer, and then flows into the vapourizer, which

is a ribbed casting of peculiar form, making an annular chamber surrounding the storage bell. The water drips on to the ribs, and the air, which has been previously heated by passing through a spiral passage inside a casing surrounding the downcomer, passes over the ribbed surface of the vapourizer and absorbs the water vapour. The whole producer casing, vapourizer, bell and hopper are made of cast iron, arranged for rapid separation when it is desired to have access to the interior of the vapourizer or producer.

Fig. 15 shows Messrs. Davey, Paxman & Co.'s producer, of which the prominent features are the form and position of the vapourizer and the rocking grate, which will readily be understood from the illustration.

Messrs. Kynoch, Ltd., make the suction gas plant represented by Fig. 16. The vapourizer and air heater combined are external to the producer, being formed as a jacket surrounding the downcomer pipe which carries a spirally formed gutter round its outside surface (forming the inside surface of the jacket), down which gutter the water trickles, whilst the air is also passing downward in the jacket space. The water feed is controlled by a regulator of the type consisting of a flexible diaphragm acted upon by the suction from the engine and lifting a valve through which the water drips more or less by its pulsations.

Fig. 17 shows a cross-section and detail of the design of the Griffin Engineering Company, in which the

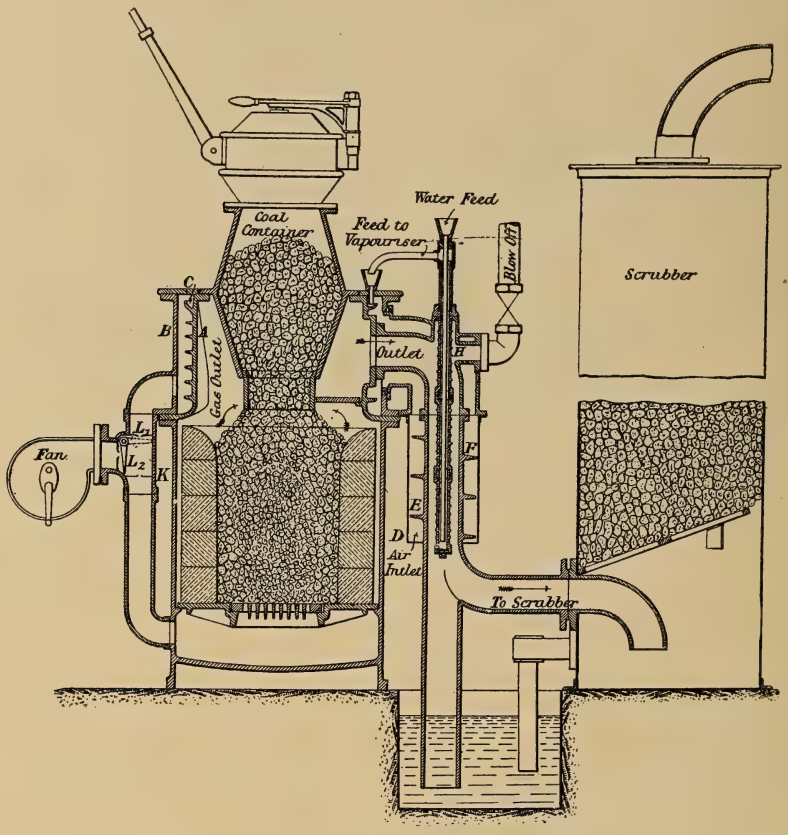


FIG. 14.—SUCTION PRODUCER PLANT MADE BY THE NATIONAL GAS ENGINE CO., LTD., ASHTON-UNDER-LYNE

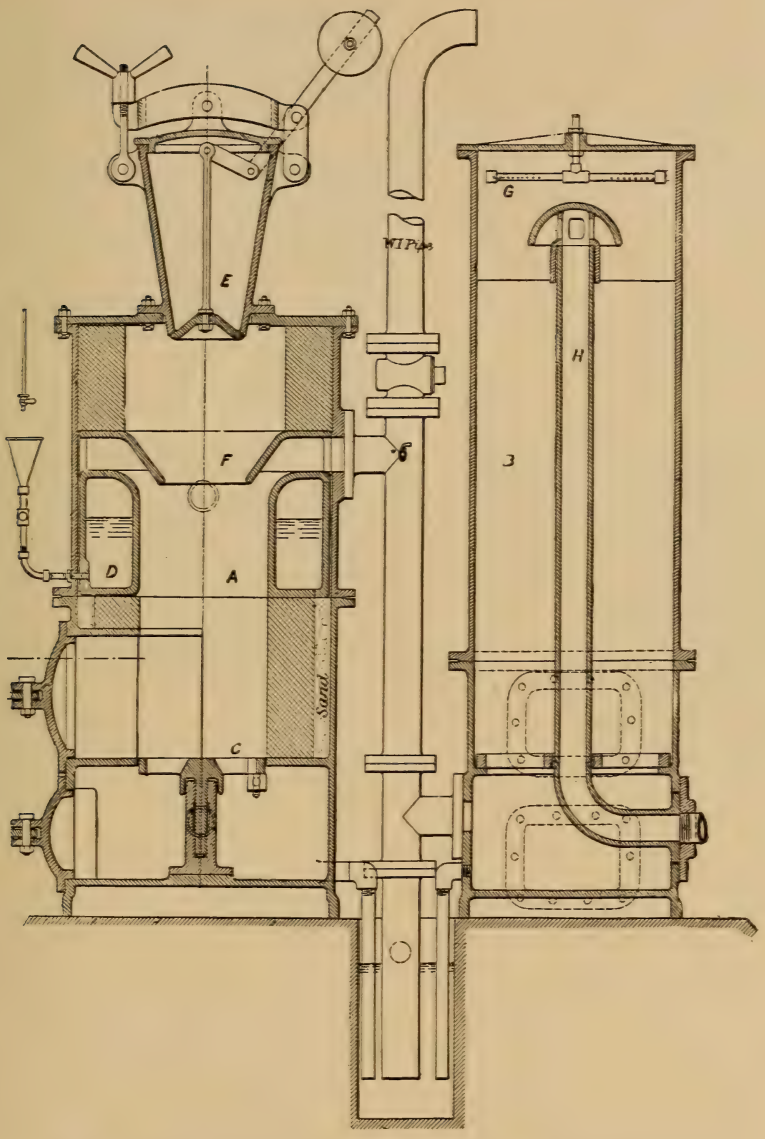


FIG. 15.—SUCTION PRODUCER BY MESSRS. DAVEY, PAXMAN & CO., LTD., LEEDS

prominent feature is the automatic feeding hopper. By means of a small cylinder which is bolted to the producer casing, and in which works a spring loaded piston under control of the suction produced by the engine, a friction feed is operated, and this gears with the worm wheel on the shaft of the revolving drum of the hopper. The rate of feed is thus governed by the action of the engine. The level of the fire is kept below the bell, so that both inside and outside surfaces are exposed to the hot gases, and this bell forms the vapourizer, as is shown. Some preliminary heating of the water takes place in the downcomer pipe.

A section of Messrs. Newton Bros.' plant is given in Fig. 18. In this

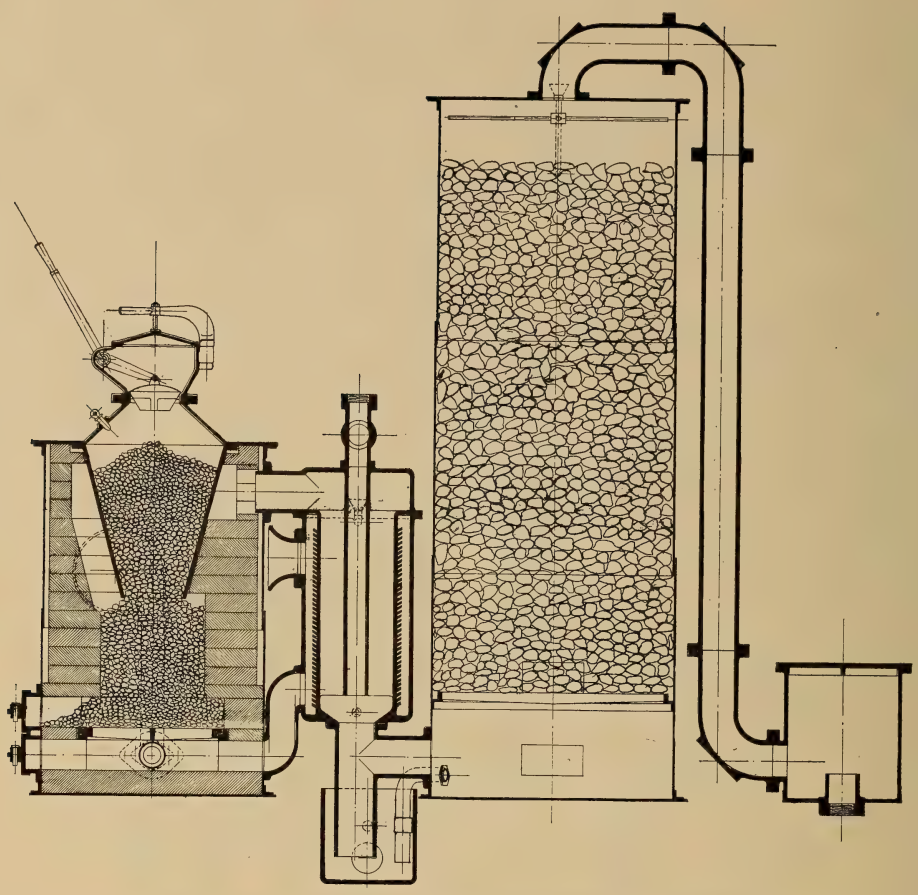


FIG. 16.—VERTICAL SECTION OF THE PRODUCER MADE BY THE KYNOCH COMPANY, BIRMINGHAM

design the vapourizer is formed of a series of ribs surrounding the outer surface of the cast-iron cylinder, which carries on its inner circumference the fire-bricks forming the furnace or generator body. This is placed concentrically within an outer cylindrical casing of wrought iron or steel plating, the annular space between the two cylinders being used for heating the air, as well as mixing it with water vapour. The air is also heated in a jacket surrounding the downcomer pipe. The water is admitted to the vapourizer by a regulator actuated by the charging strokes of the engine piston. The fire bars are placed a short distance below the furnace body to facilitate cleaning, and they have at their outer edge, or at the outer circumference, a trough-shaped projection into which water is dropped so that some steam will directly act on the clinker. Communication between the producer and the waste pipe is governed by a water seal, the water level being lowered to uncover the bottom end of the chimney or waste pipe when it is desired to blow into the atmosphere at starting up. By raising the water level that communication is cut off and the gas passes to the scrubber.

Fig. 19 illustrates the plant of the Mersey Engine Works Company. The fuel is fed through a cylindrical valve in the hopper and rests on a solid hearth, the grate bars being vertical, arranged in the form of a conical basket. The water is vapourized

partly in the space surrounding the downcomer, which is wrapped round with fibrous material and partly in a coil surrounding the storage bell. The air is heated in the downcomer jacket and in a double casing round the producer body, which is built up of steel plates and lined with fire-brick. The expansion box is combined with a chamber filled with wood fibre to dry the gas.

The "Industrial" plant, now made by Messrs. B. R. Rowland & Co., Ltd., is shown in section in Fig. 20. It combines the features of a cylindrical valve hopper feed, vapourizer partly a coil and partly a ribbed spiral surrounding the downcomer, air heated in the jacket surrounding the downcomer and in the double casing of producer body, and an exhaust fan for starting up. The fire rests on a solid hearth without fire bars.

Fig. 21 shows in section the plant of the Dudbridge Iron Works Company, in which the jacket surrounding the downcomer is used as a water heater in its lower half, the air being admitted to the same jacket just above the water surface, and then being drawn with the steam through an annular chamber surrounding the storage bell with a space for the hot gases between the two. Water is also kept in the ashpit to form steam by radiation of heat and by contact with hot ashes.

The plant of Messrs. E. S. Hindley & Sons is illustrated in Fig. 22, and that of Messrs. T. H. & J. Daniels, Ltd., in Fig. 23. In the original form of the latter, the gas was conducted by a pipe inside the producer lining down to a space under the ashpit, which space was covered by a metal plate on which water was allowed to rest and evaporate by the radiated heat from the fire. The present design utilizes the heat of the gas in the external downcomer pipe to heat the water, which is then led into a vapourizer surrounding the storage bell on the producer top, the air being passed through the vapourizer and the air and steam led down to the ashpit by an external pipe.

In addition to those enumerated, there are in practical use designs of Mason's Gas Power Company, Ltd.; the Acme Gas Engine Company, Ltd.; Messrs. Drake & Gorham, and also the Watt, Stewart, Butler,

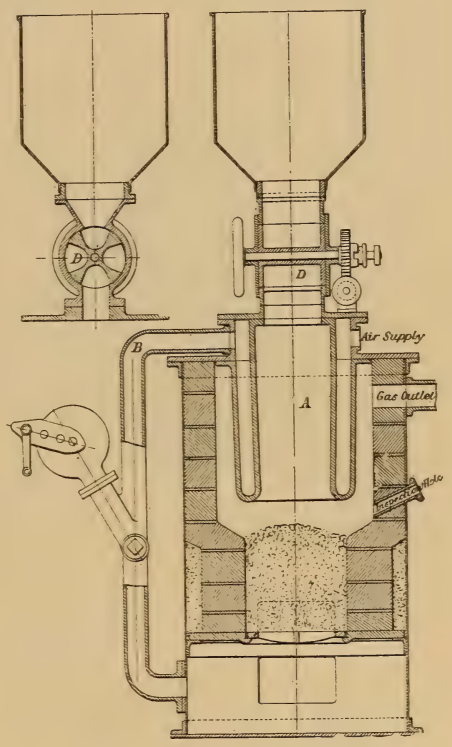


FIG. 17.—AUTOMATIC FEED FOR SUCTION PRODUCER. GRIFFIN ENGINEERING CO., BATH

Brotherhood & Paywell designs. The Kiderlin design of the producer plant was at one time made by Messrs. J. E. H. Andrews & Co., Ltd., and was illustrated in their catalogues.

Means for removing clinker and ash are provided in all designs, generally by doors opening on the ashpit, and in some few cases poker holes are also arranged. Varieties in the design or arrangement of such details of manufacture, as the water sprinklers in the scrubbers, and the like, will also be noticed, but it is

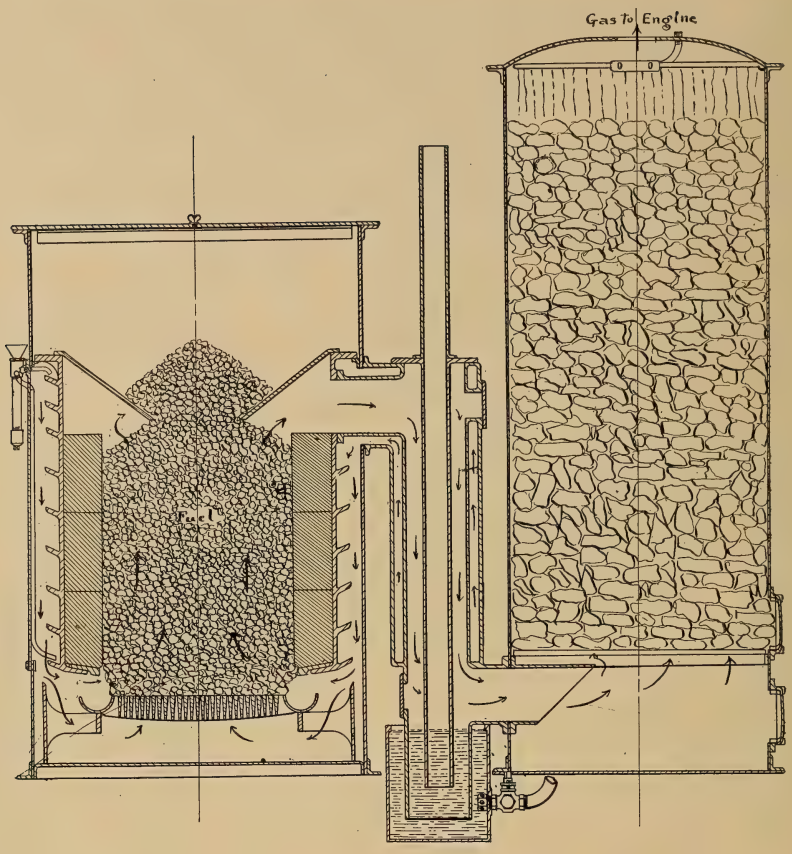


FIG. 18.—SUCTION PRODUCER OF 100-H. P. CAPACITY. NEWTON BROS., DERBY

not our purpose to enter upon any discussion of the comparative merits of the different designs.

The principal design of suction producer plant in use in France, viz., that of Messrs. J. & O. G. Pierson, of Paris, offers in several respects an interesting contrast to the British designs. Although the suction producer system was originated in France, it has not made progress in that country on anything like the scale of its progress in Britain. This seems to be greatly due to the quality of fuel which is available in that country, this fuel, it is said, being usually a poor coke, or a small hard coal with a high percentage of ash. The latter condition, with the attendant tendency to clinker formation, introduces difficulties which require special provision, and the fact that the Pierson plant has been successful with such qualities of fuel renders it of special interest. A diagrammatic sketch of the plant is given in Fig. 24. The generator is composed of an iron cylindrical body lined with fire-brick and having a conical top closed by a cover. This conical top forms a store of fuel, and usually contains sufficient for a day's supply. Where intermittent feeding is necessary, a hopper with the necessary slides or valves takes the place of the cover. Below the cylindrical body, and attached to it, is an annular boiler of inverted conical shape, which forms the combustion zone or furnace proper, and this has attached to its

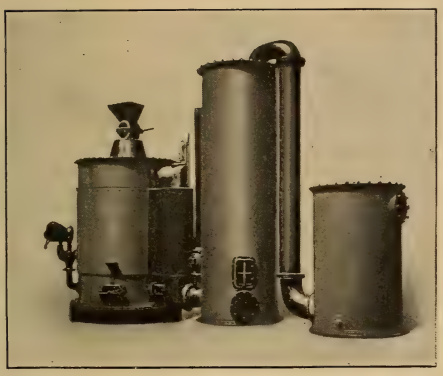


FIG. 19.—SUCTION PRODUCER BY THE MERSEY ENGINE WORKS CO.

lower edge a cast-iron hollow ring which serves to support the fuel, and to superheat the steam which is led into it before escaping from it to the fire. There is no grate and no ashpit, but a little below the cast-iron ring there is a cast-iron table or hearth lined with fire-brick, on which the ashes rest, spreading out on it in conical form. By these means ashes are easily removed, and the formation of clinkers adhering to the sides of the producer is prevented. The downcomer pipe terminates in a water seal, and a branch leads the gas into the scrubber, which contains a number of trays or shelves with numerous nozzle-shaped perforations. The gas having to pass the divisions through these perforations against the streams of water issuing by them, is washed by contact with the water there, and also in passing through the interstices of the coke or other material carried by the trays. Beyond the scrubber is a chemical purifier and drier, which removes moisture and sulphur vapours from the gas. The water level is suitably maintained in the boiler by means of a diaphragm acted upon by the partial vacuum produced. By the suction stroke of the engine piston the quantity of steam admitted to the fire is controlled. An exhausting fan is used to start up the producer. This is said to be the only French design of plant which has been completely successful with French fuel, and it is installed in the works of Messrs. Norin - Selaverand and de Dion-Bouton, which are engaged in the construction of automobiles.

RESULTS OF WORKING

As the engine forms an integral part of suction producer plant, the consumption of fuel (anthracite coal or coke), or the working cost of fuel, is always expressed in terms of the output from the engine, or in those of electrical output where the engine is used for dynamo driving. Records of tests giving such figures abound and bear witness to the fuel economy of this class of plant, and although test conditions are, as a rule, more favourable to any plant than everyday working conditions, yet there seems to be no reason to doubt that results in the neighbourhood of 0.75 pounds of coal per brake-horse-power-hour, or 1.2 pounds per kilowatt-hour, can be obtained. Better figures are, of course, on record. The fuel cost per brake-horse-power or per kilowatt-hour is necessarily influenced by the price of coal per ton at the plant, and, therefore, is not by itself a complete statement of fuel cost. The total cost of power, of course, includes several other items.

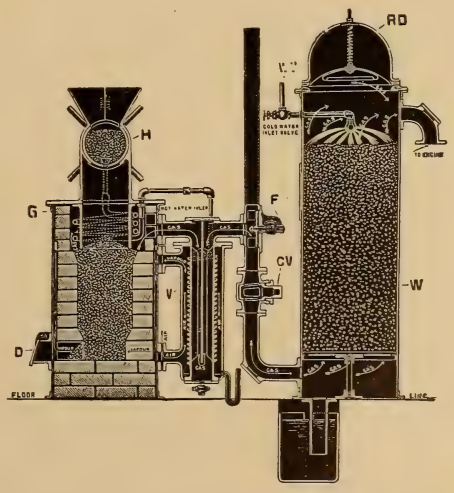


FIG. 20.—INDUSTRIAL GAS PRODUCER. B. R. ROWLAND & CO., LTD., REDDISH

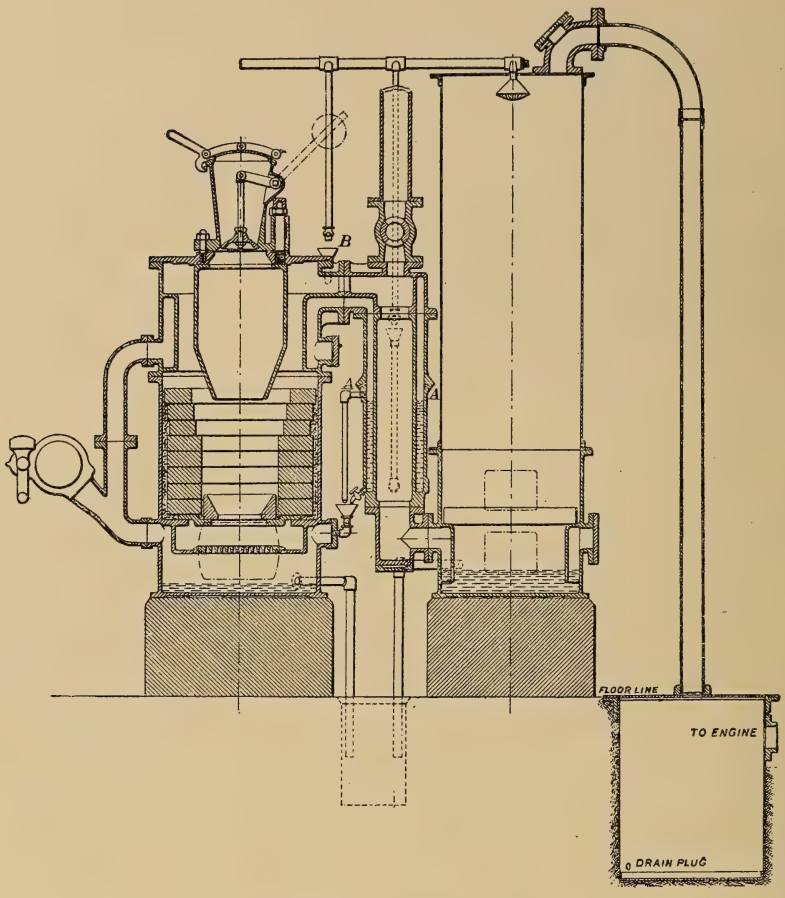


FIG. 21.—THE DUDBRIDGE IRON WORKS SUCTION GAS PRODUCER

The Dynamic Company claims to have shown fuel costs of 0.253 pence per brake-horse-power, or 0.316 pence per kilowatt-hour, in the case of their suction plant at Trafford Park, and even 0.06 pence per brake-horse-power-hour in the case of a continuous working plant of 150 brake-horse-power running on Scotch anthracite.

Crossley's "Howrah" test showed a fuel consumption of 0.91 pound of coal per brake-horse-power-hour, or 1.325 pounds per kilowatt-hour, with a thermal efficiency of producer plant of 89.5 per cent. Dowson claims for a 40 horse-power plant an efficiency of 89 per cent., and for a 30 horse-power plant an efficiency of 86 per cent.; and Campbell gives the fuel consumption and cost at Broxburn electric power station, with an 80 brake-horse-power gas engine and suction plant, as follows: On a six and three-quarter-hour test run, anthracite coal consumed per brake-horse-power-hour 0.075 pound, per kilowatt-hour 1.07 pounds; cost per brake-horse-power-hour 0.05d., per kilowatt-hour 0.06d.; on a twenty-nine days' working test, consumption of fuel per brake-horse-power-hour 1.25 pounds, per kilowatt-hour 2.09 pounds; cost of fuel per brake-horse-power-hour 0.08d., per unit 0.138d.; cost of fuel in bunker 12 shillings per ton.

The following figures are taken from the report of trials at Glasgow show, 1905:

	20 B.H.P. Capacity—Full Load.				8 B.H.P. Capacity—Full Load.			
	Campbell.	Crossley.	National.	Tangye.	Campbell.	Industrial.	National.	Tangye.
Declared B.H.P. at full working load	18.	16.	20.	19.	8.	13.5	8.	7.5
Duration of trial, hours	10.	8.12*	10.	10.	10.	10.	10.	10.
Brake-horse-power	20.44	15.35	20.57	19.98	8.25	9.72	9.74	8.34
Total coal used, lbs.	190.0	96.5	165.75	166.0	100.75	110.25	82.0	100.5
Coal per B.H.P. hour	0.93	0.77	0.80	0.83	1.22	1.13	0.84	1.25
	20 B.H.P. Capacity—Half Load.				8 B.H.P. Capacity—Half Load.			
Duration of trial, hours	10.	10.	10.	10.	10.	8.43*	10.	10.
Brake-horse-power	10.69	9.06	10.48	10.72	4.43	4.36	5.36	4.57
Total coal used, lbs.	98.0	87.25	100.25	116.0	41.5	56.75	49.0	67.5
Coal per B.H.P. hr., lbs	0.92	0.96	0.95	1.08	0.94	1.55	0.91	1.48
Average consumption per B.H.P. hour on full and half load combined, lbs.	0.93	0.86	0.86	0.92	1.12	1.26	0.87	1.30
Capacity of producer per declared hp. cubic feet	0.232	0.270	0.295	0.124	0.282	0.161	0.372	0.212

* In these cases the trials were not completed owing to a temporary stoppage.

In the trials of the suction gas plants at the Royal Agricultural Society's show at Derby in 1906, eleven plants were fully tested, and the abstracts of results, as stated by Mr. Horace Allen, in the "Practical Engineer," are as follows:

ELEVEN SUCTION GAS PLANTS AND TWO GAS ENGINES FROM 15 TO 20 B. H.P.

	Anthracite, Pounds.	Coke, Pounds.
Consumption of fuel per square foot of cross-section of furnace	Average 23.9 Maximum 39.2 Minimum 16.5	26.2 45.7 17.0

The consumption per brake-horse-power per hour of these plants was:

	Full Load, Pounds.	Half Load, Pounds.
Anthracite	1.0 to 1.48	1.38 to 1.98
Average of 11 plants	1.21	1.65
Coke	1.21 to 1.65	
Average of 11 plants	1.42	

The amount of clinker resulting from a day's run was found to vary as in the table on page 196.

The consumption of water per brake-horse-power-hour in these tests, including water used in the producer for vapour and water used in the scrubber for cooling and purifying the gas is tabulated on page 196.

"Most of the water was employed in the purifying apparatus, and a test of the amount of water used in the vapourizers of four of the plants while running on coke fuel, showed that it varied from 0.08 to 0.5 gallon per brake-horse-power per hour, the average being 0.25 gallon. This is equivalent to about 1.7 pounds of water per pound of coke on average during full load trial." The full figures for all the plants tested are given in the tables contained in the report of the judges.

Various statements of comparative stand-by losses in gas plants and steam plants have appeared, and also comparisons of space occupied by the two kinds of plant, and the economy of gas plants under both heads is considerable and undoubted. Suction gas plants require the minimum

ROYAL AGRICULTURAL SOCIETY TESTS, DERBY, 1906. CLINKER FORMED

	Weight of Clinker.		
	Maximum Pounds.	Minimum Pounds.	Average Pounds.
Anthracite 11 plants	7.3	1.0	3.15
Coke 11 plants	6.0	0.2	1.53

ROYAL AGRICULTURAL SOCIETY TESTS, DERBY, 1906. WATER CONSUMPTION

	Anthracite, Full Load.	Anthracite, Half Load.	Coke, Full Load.
Gallons per B.H.P. per hour	.73 to 3.61	.52 to 3.61	1.40 to 5.76
Average	1.88	1.85	2.99

of space and of attendance, and the cost of upkeep of producer plant (excluding engine) is stated by H. Campbell to be about £3 per annum for 50 brake-horse-power, ranging up to £15 per annum for 500 brake-horse-power. Even if these amounts were doubled, they would still constitute a very small tax on capital involved.

LIMITATIONS AND UNSOLVED PROBLEMS

In its earlier days it was thought by many that the suction gas producer would find its useful limit at about 150 to 200 horse-power, but that has already been successfully passed, and manufacturers variously offer to install plants of 300, 500, 700 and even 1,000 horse-power in single units. When it is considered that 1,000 horse-power represents the gasification of only about 12 cwt. of anthracite coal per hour, that problem does not now seem to be beyond the capacity of a good suction plant. There is more reason to fear that, as has been indicated, at the larger powers pressure-producer plant, from its quicker rate of gasification, and,

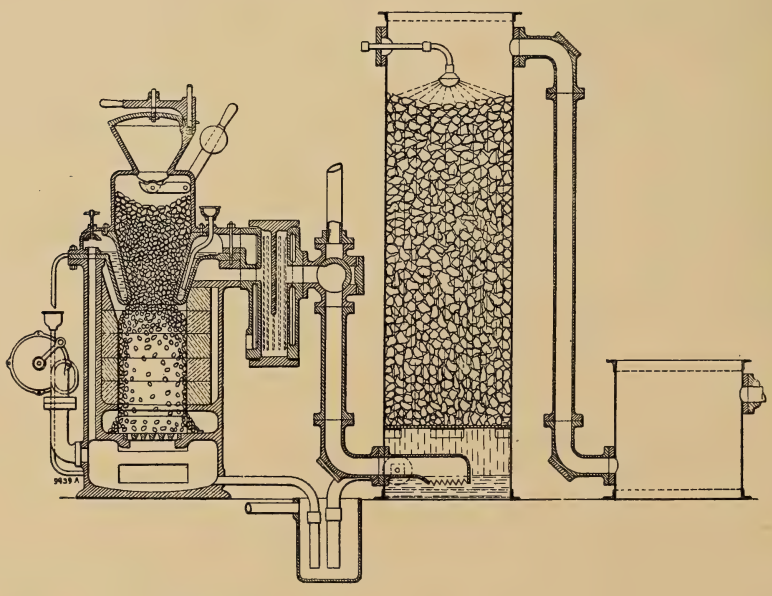


FIG. 22.—SECTION OF GAS PRODUCER MADE BY E. S. HINDLEY & SONS, LTD., BOURTON, DORSET, ENGLAND

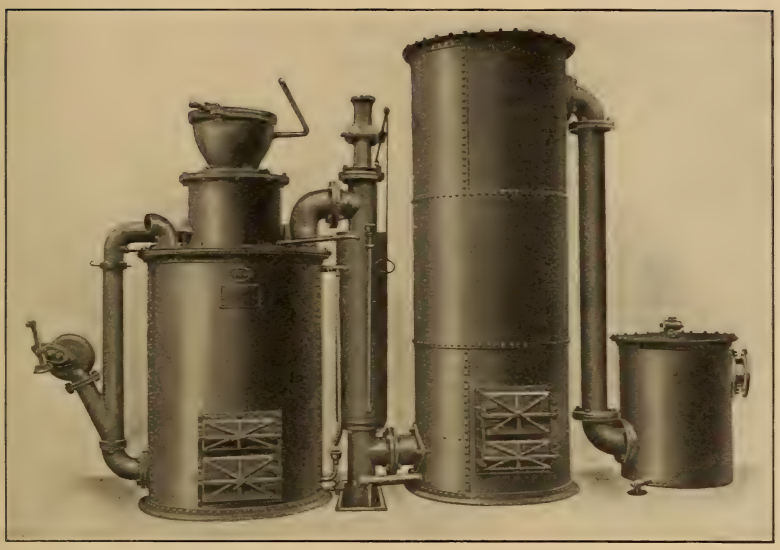


FIG. 23.—SUCTION PRODUCER PLANT BY T. H. & J. DANIELS, LTD., STROUD, GLOUCESTERSHIRE, ENGLAND

therefore, not proportionate increase in size, and its capability of using the cheaper form of fuel found in bituminous coal slack, will seriously rival the suction plant employing the more expensive anthracite or coke. There still remains the possibility of devising some form of suction plant which will employ bituminous coal successfully, and to this problem, epecially in view of its great importance to the application of the gas engine to marine use, much attention is being directed. The great difficulty is undoubtedly that of the tar, and bulky cleaning apparatus being inadmissible on board ship, it seems to be imperative that the tar should be destroyed or transformed into permanent gas by heat in some way. Many plans have been proposed for effecting this in the producer itself,

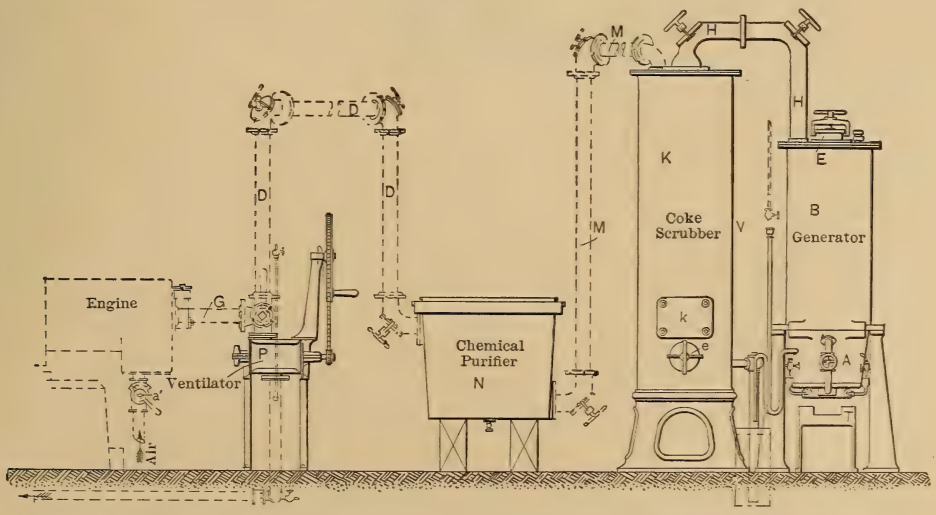


FIG. 24.—SUCTION GAS PLANT MADE BY MESSRS. J. & G. O. PIERSON, PARIS

or in a secondary chamber containing incandescent coke, but as yet none has been completely successful. On shore, with greater freedom of access to space, and freedom from limitations of weight, the tar problem can be attacked with condensing plant which, when combined with recovery of other products and suitable means for heat recuperation, can be made to yield a substantial profit.

Another promising direction in which the usefulness of the suction gas system can be increased is that of a further development of the recuperation of heat at present wasted in the producer plant and engine. In fact, for all applications of the gas engine it is important that the large amount of heat dissipated in the exhaust gases and jacket water should be turned to useful account. We are told that a 500 brake-horse-power gas engine can thus supply heat sufficient for an additional 50 brake-horse-power steam installation if using steam at 20 pounds per indicated horse-power-hour, and that is surely an economy which is worth our consideration.

POWER GAS FROM BITUMINOUS COAL

By Elbert A. Harvey

THERE seems to be a general lack of information as to whether the use of producer gas from bituminous or soft coal is a practical and operating success, or whether it is still in the experimental stage with results good enough to promise well for the future, but not sufficiently well established to warrant the use of this gas in large power plants where continuous and uninterrupted operation is required.

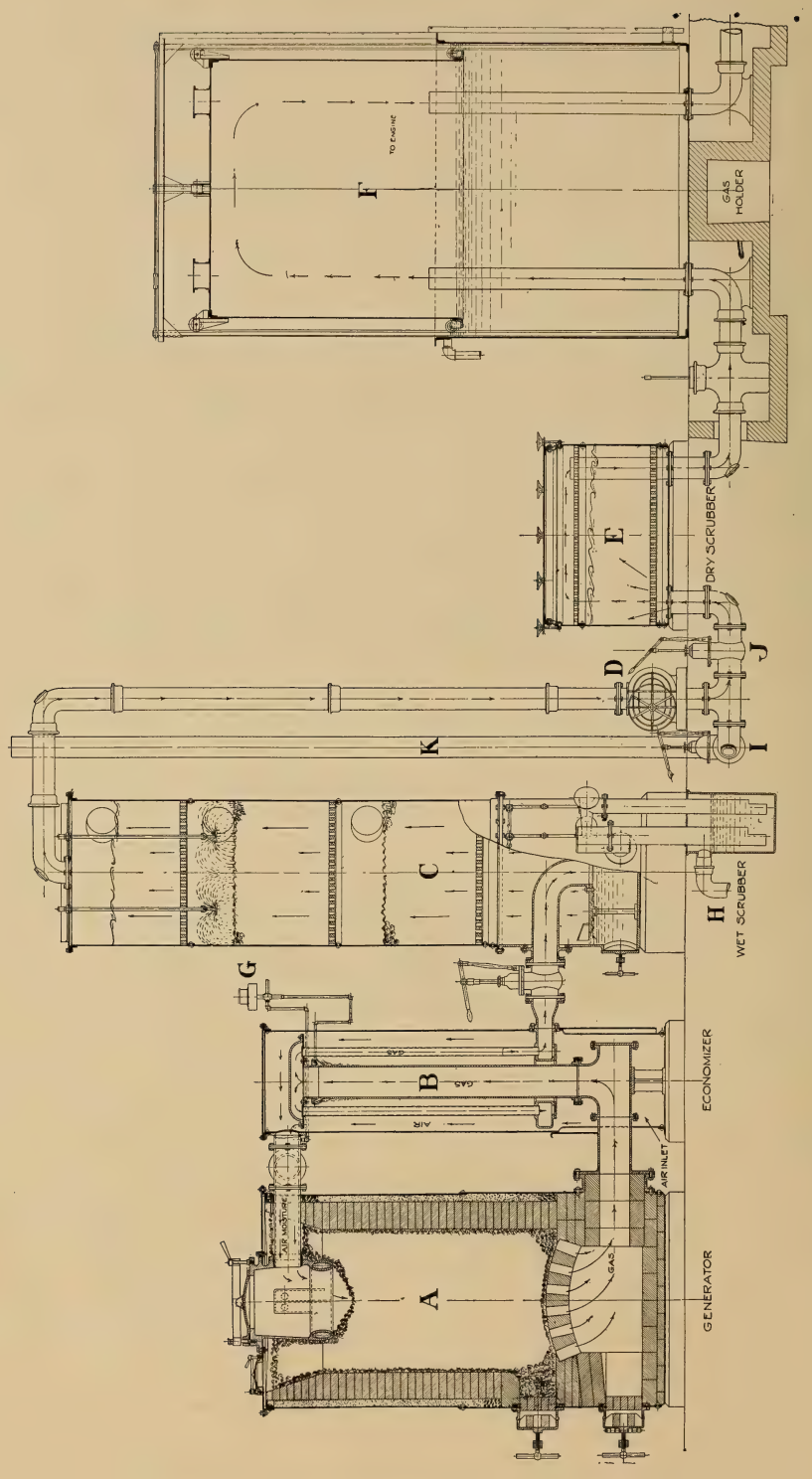
First of all, let it be said, and said emphatically, that the use of bituminous producer gas for power is a success, both practically and commercially, and there are in the United States to-day a number of gas power plants where bituminous coal is used, and some where the gas engines are operated twenty-four hours every day in the year, and there are at least three different companies manufacturing bituminous gas power plants which have already achieved success.

The lack of information on this subject, and the lack of confidence in the bituminous power producer, is largely accounted for by the fact that there have been during the past few years a great many projected bituminous producers which have been failures, or at least only partial successes, and the dust stirred up by these has largely obscured the real progress which has been made.

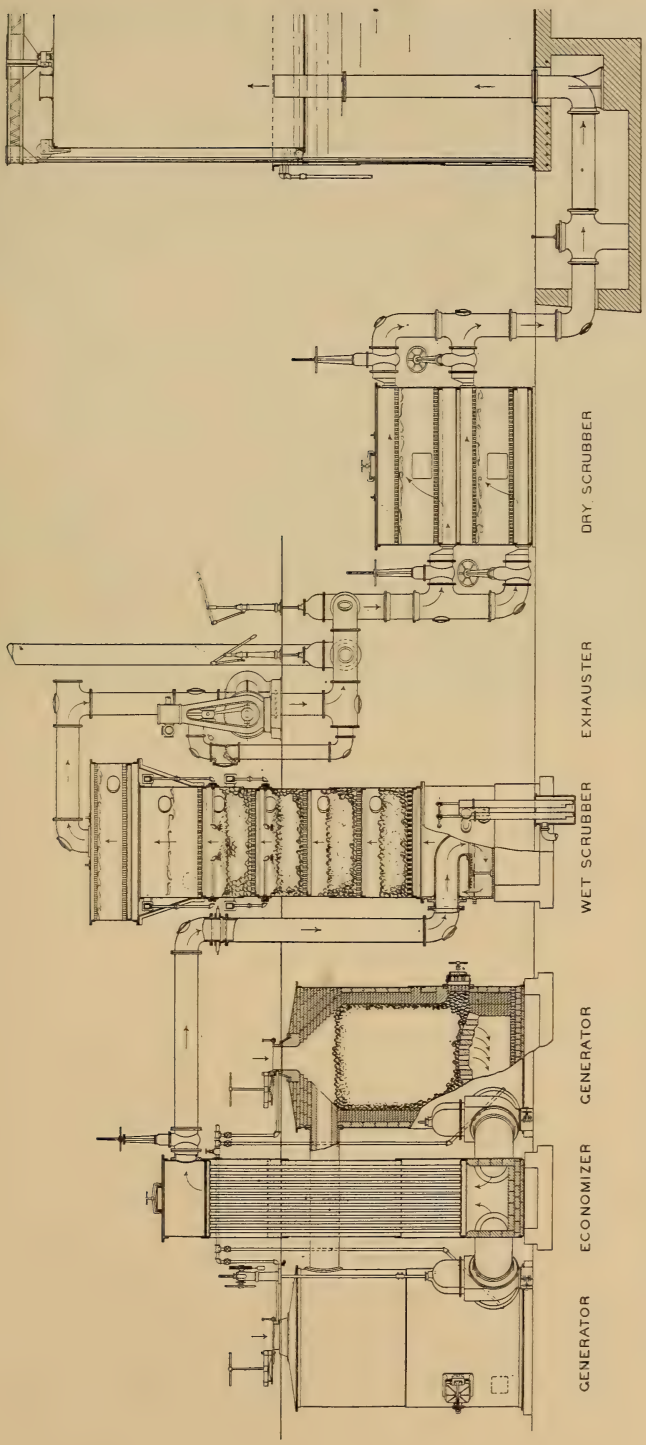
The first apparatus to come prominently into the field was the Loomis-Pettibone plant. This was the product of Messrs. Burdette Loomis and H. Pettibone, now consulting engineers in New York City. The apparatus has been in several hands, and is now owned by the Power & Mining Machinery Company, one of the constituent companies of the International Steam Pump Company, whose headquarters are in New York. A number of these plants have been installed, principally for power purposes, and they are scattered throughout the United States and Mexico. The Loomis-Pettibone plant was a pioneer apparatus, especially applicable for use with large units. It is a successful apparatus where properly handled, and has for many years been practically the only bituminous power producer in the field.

The next successful plant to enter the field was offered by R. D. Wood & Co., of Philadelphia. Their plant embodied the ordinary updraught producer, such as has been used in the steel and glass industries for years, but also included an apparatus for mechanically removing the tar and soot from the gas. One of these plants was installed for the United States Geological Survey at the government testing station at the St. Louis World's Fair, and a number have since been installed elsewhere. This plant is successful, but also has a number of apparent limitations. These limitations, however, are due rather to the arrangement of details than to the general design of the plant, and it would seem that the R. D. Wood producer is the first of the type which will prevail.

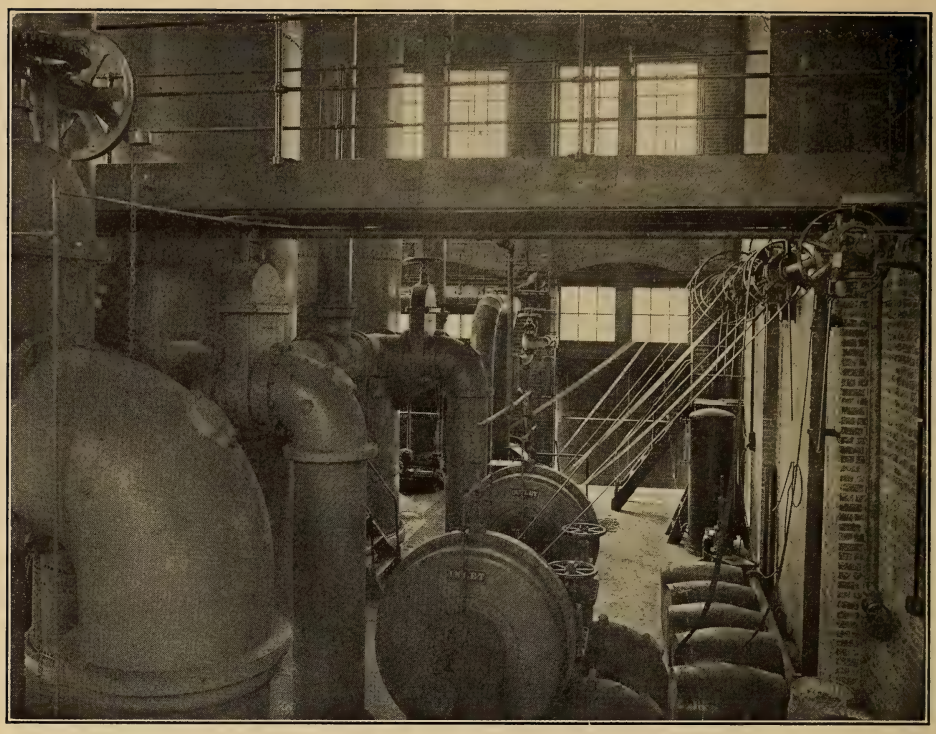
This year there has been launched onto the market another producer of the same type as that of R. D. Wood & Co., with improvements in detail, rendering it available for uninterrupted and continuous service. This plant is built by the Industrial Gas Company, of New York.



GENERAL ARRANGEMENT OF SINGLE-GENERATOR LOOMIS-PETTIBONE PRODUCER, ADAPTED FOR PLANTS UP TO 500 HORSE-POWER. POWER AND MINING MACHINERY CO., MILWAUKEE, WIS.



DOUBLE-GENERATOR LOOMIS-PETTIBONE GAS PLANT FOR UNITS FROM 500 TO 2,000 HORSE-POWER. POWER AND MINING MACHINERY CO., MILWAUKEE, WIS.

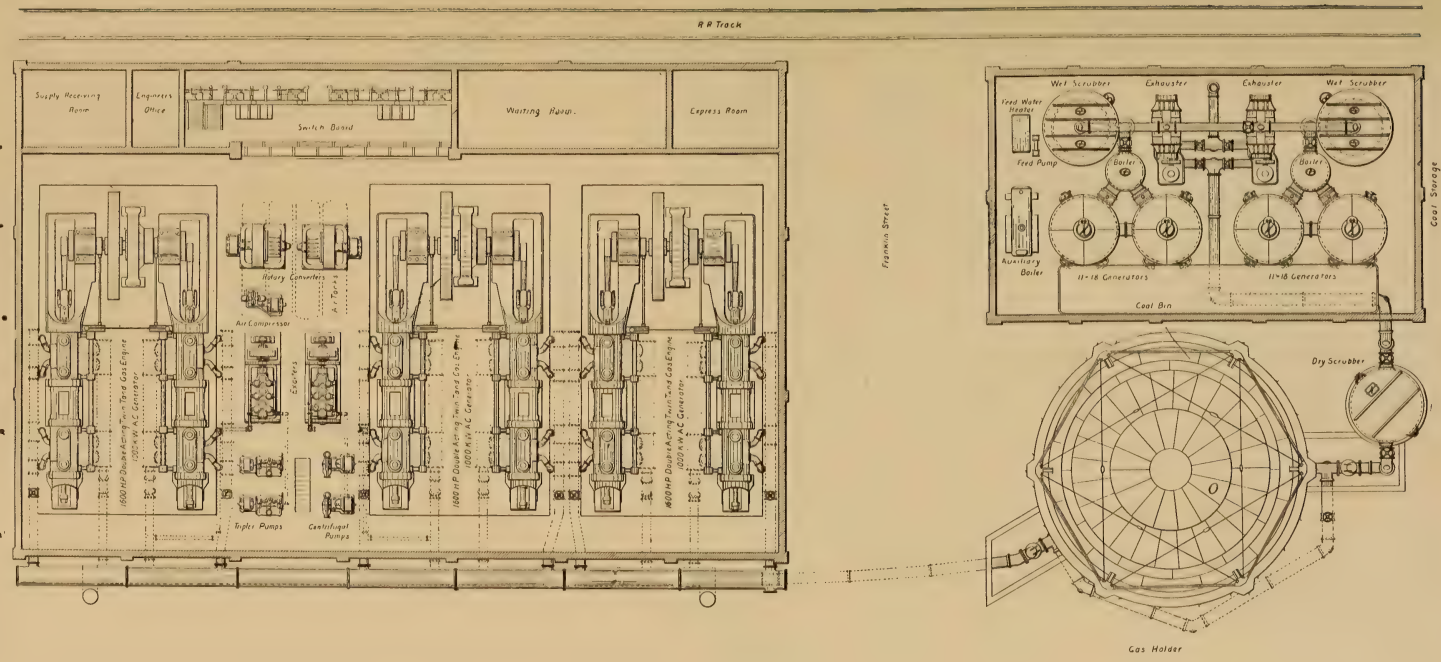


GAS PRODUCER PLANT FOR BOSTON ELEVATED RAILWAY CO., 1,500 H. P., ARRANGED FOR USE WITH BITUMINOUS COAL. R. D. WOOD & CO., PHILADELPHIA

There are several other bituminous power producers now in the field, but up to the present time none of these have won their spurs, and it would appear from present indications that some of them will not survive their infancy.

It is interesting to compare these three succesful producers because the Loomis-Pettibone and the Wood types of producers, the downdraught and updraught, and because the Industrial illustrates the latest improvements in the updraught type, which type will probably become the prevailing one. Yet strangely enough, most of the newly projected producers are of the downdraught type, but up to the present time the Loomis-Pettibone plant, the pioneer, is the only notably successful representative of the class.

The characteristic difference between anthracite and bituminous coal, so far as gas making is concerned, lies in the presence of hydrocarbon matter in the coal. The absence of hydrocarbon matter renders the process of making producer gas so simple that immediate success seems to attend almost every effort to build an anthracite producer apparatus, and as a result there are already scores of firms building anthracite producers, and most of them are successful, or at least workable; but this is not the history of the bituminous producer. The path made by projected producers of this type is strewn with scrap material, worthless stock certificates, and engineers with more experience than standing. Many different plants have been tried, but few have worked, and the hydrocarbon matter is the principal cause of all the failures. To the ordinary man the word "hydrocarbon" is simply a chemical term; to the organic chemist the term embraces half the universe; but to the ex-



GAS-POWER PLANT OF THE MILWAUKEE NORTHERN RAILWAY, FORT WASHINGTON, WIS. 4,000-H. P. LOOMIS-PETTIBONE GAS PLANT, ALLIS-CHALMERS GAS ENGINES AND ELECTRIC GENERATORS. THE LARGEST STREET RAILWAY PLANT USING BITUMINOUS COAL IN GAS PRODUCERS

perienced gas man the term is a nightmare, and yet it simply means a substance compound of hydrogen and carbon, but there are an unlimited number of variations of this combination, and these variations run from light gases through heavy gases, light liquids and heavy liquids, down to tarrish liquids and solids, and these forms are not stable, but readily change from one to another, and sometimes separate entirely, leaving pure carbon as a solid in the form of soot.

Bituminous coal is composed largely of hydrocarbon matter, in some grades amounting by weight to nearly one-half. The fixed carbon represents the principal portion of the balance of the coal, and this portion of the coal is the same as in anthracite. When bituminous coal is heated, the hydrocarbon portion is volatilized or driven off in the form of a gas, or rather a combination of many different gases. Some of these are real gases; that is, they remain as gases after cooling, and are termed "fixed." Others cool into oils, others into tars, and others "crack" or separate in such a way as to deposit their carbon in the form of soot. The heating of bituminous coal, therefore, always causes the immediate driving off of the hydrocarbons, and these form or produce three distinct products:

1st.—Fixed hydrocarbon gases.
2d.—Liquid hydrocarbons or tars.
3d.—Pure carbon or soot.

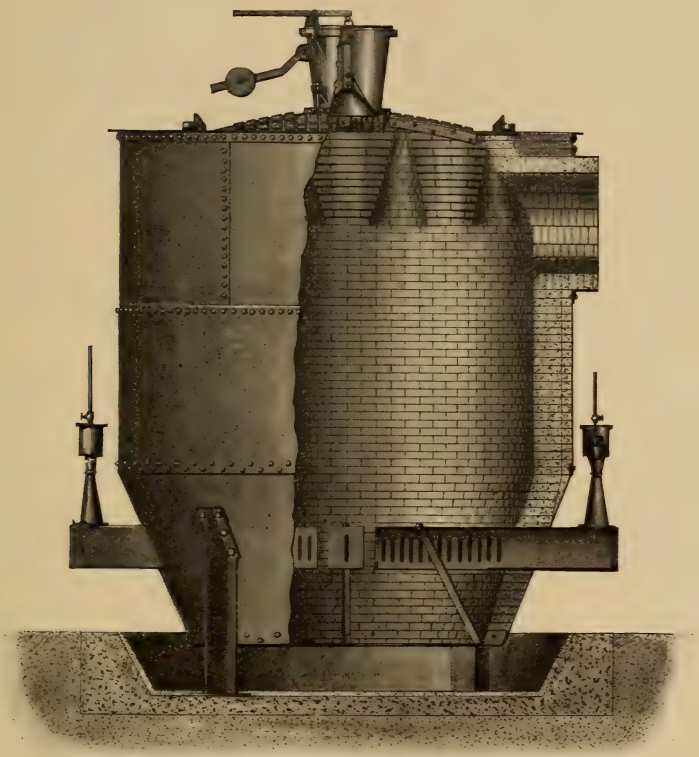
The first of these products is good in every respect, a group of clean fixed gases of high heat value, and in every way suitable for gas engines. But the tars gum and clog up the gas pipes and engine valves, and soon put a stop to all operations, and the soot is even worse.

One of two methods must be followed. Either the tar and soot must be burned out, as in the Loomis-Pettibone process, or they must be removed mechanically, as in the Wood and Industrial processes. The former method seems more attractive, as it seems better to gasify than to waste the tar, which has a high heat value, and would be a useful fuel if it were not for its gummy consistency. But in practice the latter method is found to be the simplest and the best, and in the case of the Industrial plant the tar is not wasted, but is burned as fuel in an auxiliary steam boiler used to develop power for the operation of the gas plant.

To compare the two principles of gas making, the updraught and the downdraught, it is necessary to bear in mind how producer gas is made, viz., by the semi-combustion of carbon. This primary process is alike both for anthracite and bituminous coal, for when the bituminous coal is first heated the hydrocarbon matter is driven off, and the remaining portion is coke or approximately pure carbon, which is practically identical with anthracite. The producer gas process proper may, therefore, be considered, in the case of either anthracite or bituminous coal, as consisting of the semi-combustion of pure carbon. When carbon is burned with all the air necessary for complete combustion, it is converted into carbon-dioxide, CO_2; but when it is burned with only half the air necessary for complete combustion it is converted into carbon-monoxide, CO. This is the producer gas process, and CO is the principal fuel element of producer gas. It is a colorless fixed gas with a very high flame temperature, and it burns with a very small amount of air, as it is already combined with just one-half the total amount of air with which it can combine.

The producer gas process is amplified by using a small amount of steam. This is passed through the fuel bed and decomposed by heat. This process absorbs part of the waste heat formed by the semi-combustion of the carbon, and this heat is added to the gas in the form of latent heat of the hydrogen liberated from the decomposed steam.

In the downdraught process, the



THE HERRICK GENERATOR

The Generator, or Producer, used by the Industrial Gas Company, New York, covered by the Herrick patents, including the use of a tuyere entirely embedded in the ashes, the tuyere having suitable air ports in the sides.

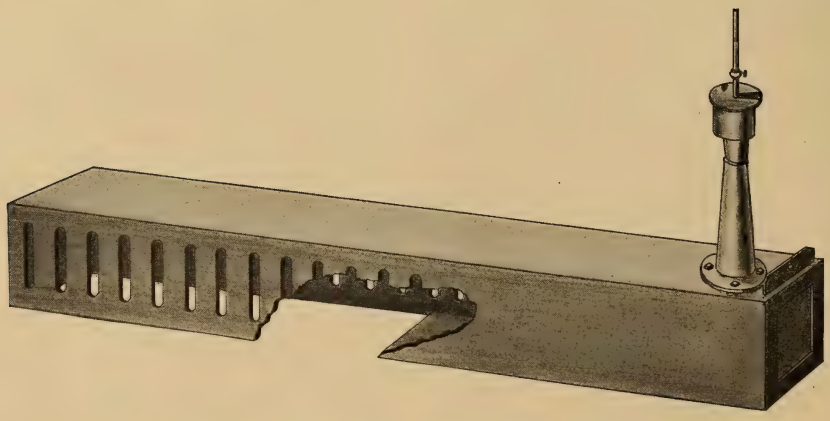
object is to convert the carbon of the hydrocarbon into CO, just as the fixed carbon of the coal is converted, and to liberate the hydrogen of the hydrocarbon in the same way as the hydrogen of the steam is liberated. When updraught is used the hydrocarbons are volatilized and driven off from the fuel bed and out of the gas producer before any air can be brought into contact with them. This is because in the updraught process the air and steam are introduced at the bottom of the generator and pass upward through the fuel column. By the time, therefore, they reach the top of the fuel column where the hydrocarbons are driven off, the steam is decomposed and the air has already combined in semi-combustion with the carbon of the coal. For this reason whatever carbon is separated from the hydrocarbons in the form of soot, passes out with the gas as soot instead of being burned by semi-combustion into CO. Furthermore, most of the hydrocarbon matter passes out in the form of heavy tars temporarily gasified by heat, whereas when downdraught is used the hydrocarbon matter is all carried down through the fuel bed in immediate contact with the air and steam which are introduced into the producer for gas making. As the result, the carbon which is freed in the form of soot is burned into CO, just as the fixed carbon of the coal is, and the heavy liquid hydrocarbons or tars, instead of being temporarily gasified and passing out of the generator to immediately condense back into tars, are "cracked" or decomposed

chemically, forming light hydrocarbon gases, most of which pass down through the generator unchanged and unburned and form a valuable part of the gas, also forming or freeing additional pure carbon in the form of soot, which is also burned by semi-combustion into CO. This process theoretically makes a perfect producer gas containing only CO and hydrogen as fuel elements, and if it could be carried out as easily as it is described, there would probably be no other process in use and the downdraught producer would have the field without a rival; but as a matter of fact, it cannot be carried out without encountering serious difficulties and complications in operation.

In the first place, soot is formed faster than it can be burned by semi-combustion, and this interferes with continuous operation. The Loomis-Pettibone apparatus is based on a recognition of this fact, and, therefore, provides two generators and a large gas holder, so that periods of gas making in each generator can be alternated with periods of cleaning out the soot by means of steam and by air blast, whereby the soot is completely burned and the products wasted. This arrangement makes the plant workable, but at the same time involves large and expensive apparatus and continuous and skillful labour. There is, furthermore, great wear and tear on the apparatus and waste of gas which reduces the theoretical efficiency. On the other hand, the system is workable, and in good hands is completely dependable, and deserves great credit as the first in the field and the only success in its class. It is doubtful if gas making by any downdraught process will be successful for continuous operation up to full capacity in any apparatus very much simpler than that of the Loomis-Pettibone plant. It is certain, however, that the temptation to produce such apparatus seems too great to be with-

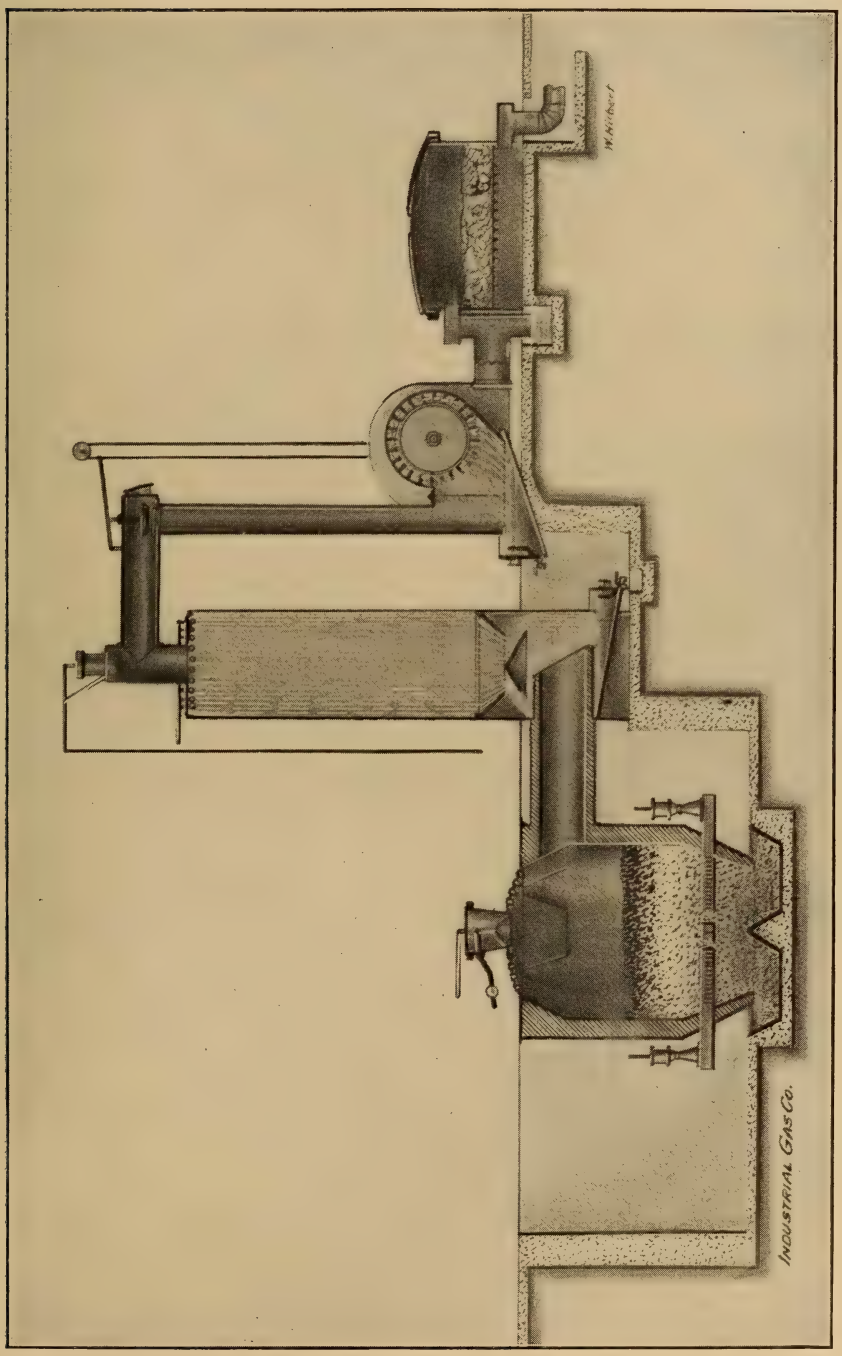
TDE BRICK-STUDDED TOP OF THE HERRICK GENERATOR

This is a heavy cast-iron top thickly studded with fire brick which are cast into the metal, providing a dry, cool and durable top without water cooling.



TUYERE AND STEAM BLOWER OF THE HERRICK GENERATOR

Each generator is equipped with three or four individual tuyeres, each with its steam blower. These are cast-iron boxes open at the bottom and provided with slots in the sides and ends to project through the producer sides into the ash; steam and air for gas making passing out through the slots into the ash and thence up through the fuel column.



HARVEY BITUMINOUS PRODUCER GAS PLANT

Sectional drawing illustrating the entire plant, showing the Herrick Generator, or Producer, the Cooler, the Wet Scrubber, the Tar Washer, and the Dry Scrubber, with water sealed top, also showing the tar collecting and burning apparatus with auxiliary steam engine and boiler.

stood, and most of the recent gas plant failures have been along this line.

In the Wood and Industrial gas plants there is no attempt to burn the tar and the soot in the gas plant itself. The gas leaves the producer carrying its full quota of tar and soot. From the producer it is carried to a cooling tank, where it is subjected to a shower of water to lower the temperature. From this tank the gas is taken to a rotary washer, where it is whirled and beaten and subjected to a further water shower. In this washer the tar is separated from the gas and collected out by settling in water. From the washer the gas is led through a large tank containing excelsior or other absorbent material, which removes the moisture, and then the gas is discharged into the pipes to be led off to the engines.

The industrial plants are equipped with tar-burning apparatus. The tar is collected in a trough attached to the washer; from there it is drawn by gravity into a storage tank. Periodically this storage tank is closed and the tar forced by steam pressure into a gravity feed tank located over an auxiliary steam boiler. The tar is kept fluid by heat from steam pipes, which are run at all points throughout the tanks and in the connecting pipes. The boiler is used to furnish steam to the producers for gas making, and also to the steam engine used to operate the rotary washer.

With this arrangement the tar by-product is used to carry on the gas-making process. It is, therefore, not wasted, and its use renders the gas plant self-operative, so that the generator efficiency becomes the net efficiency for the entire plant.

The principal differences between the Wood and the Industrial plants lie in the generators, or producers proper, and the tar washers, both of which in the Industrial equipment are rigidly protected patented articles.

The Herrick generator is the producer used by the Industrial Gas Company. It is without question the best hand-fed, hand-poked producer to-day in the field, as is attested by the many producers of other makes which are constantly being changed over to the Herrick design. The Herrick generator is a steel cylinder with firebrick lining, without grate, and with open bottom closed by a water seal contained in a concrete pit or basin. The ash rests on the bottom of the pit and supports the fuel column without any apparatus whatever. The producer is accessible from all sides for ash removal, which is accomplished by simply shovelling the ash out under the water. This does not interrupt gas making, and renders continuous service possible. The air and steam for gas making are introduced into the fuel column through tuyeres, or hollow cast-iron boxes, projecting at four different points from the sides into the ash column. These boxes contain a number of slots in the sides through which the air and steam pass out in the ashes and up through these into the fuel. This arrangement embodies the principal Herrick patent, and secures the most uniform distribution of the air and steam that has been obtained by any producer arrangement. On account of this feature the Herrick generator has larger capacity than other designs, can handle slack coal, and can be counted on absolutely for twenty-four-hour service without trouble from clinkers. Another unique feature of this producer is the brick-studded top provided with firebrick cast directly into the metal. This secures a cool, dry and tight top without the use of water cooling, and it is the only top in use to-day which does not require water cooling.

The washer of the Industrial plant is clearly at the head of its class. In fact, it is the first, and, up to the present time, the only washer which can be relied upon for continuous twenty-four-hour service. Its history

so far is brief, but it is one of triumph in a difficult field, and it is perhaps more to this washer than to any other device yet developed that the use of bituminous coal for power in connection with continuous service is to-day the emphatic success which it is.

The washer is a powerfully built rotary machine, which operates at comparatively high speeds, from 500 to 1,000 revolutions per minute. The machine is designed to utilize the principle of centrifugal force, and so nicely does it do its work that the tar is discharged through one opening and the gas through another, while the machine itself does not become gummed up so as to necessitate shut-downs for cleaning. With other tar-cleaning apparatus it is the custom to have two machines, so that one can be always idle for cleaning purposes. This is entirely unnecessary with this apparatus. It does not clog up, it needs no cleaning, the operation is self-cleansing, and, therefore, continuous. A single machine is all that is necessary, and it can be absolutely relied upon to run straight through the year.

Another feature of the Industrial washer, and perhaps a more important one, is that it really does clean the gas. The gas is free from all traces of tar, and, as a consequence, the gas engine valves do not require cleaning any more frequently than when natural gas is used.

In addition to the generator and washer, one of the features of the greatest interest which marks a step towards the perfecting of practical gas apparatus is the water sealed cover of the dry scrubber. This is carried by a chain hoist and can be lifted in a few seconds of time, and the excelsior removed and replaced with a hay fork. The usual method of cleaning through man-holes seems hopelessly slow and cumbersome after one has once seen this simple and practical arrangement.

The Industrial plant is a going and operating success; it bears the earmarks of detailed acquaintance with working conditions. It is the product of men who know and do, and not of mere draught-table engineers, and it marks the day when the bituminous producer for power leaves the borderland of success and takes its place along with the steam engine and electric generator as one of the serviceable and dependable machines of the industrial world.

The gas from this type of gas plant—that is, the Industrial type with updraught producer and rotary washer to remove the tar mechanically—is becoming known as scrubbed bituminous producer gas, and this type is emphatically the most useful of all the producer gases. It is richer than anthracite producer gas, averaging 140 B. T. U. as against 125 B. T. U. per cubic foot, and it has a higher flame temperature. It is also richer than the downdraught gas; in fact, it is a very complete and satisfactory substitute for natural gas; for while it contains only 140 B. T. U., or thereabouts, as against 850-1,000 B. T. U. per cubic foot for natural gas, its flame temperature and flame efficiency are nearly as great as those of natural gas. This is because it burns with very much less air.

Scrubbed bituminous producer gas is an ideal power agent when used in gas engines, and it is rapidly proving itself to be pre-eminently satisfactory for almost every line of heating work, ranging from the small open burner to the largest heating furnaces. This type of gas made from bituminous coal in a simple, dependable apparatus, and suitable for almost every line of manufacturing work, is the gas for which the industrial world has long been waiting.

POWER TRANSMISSION BY PRODUCER GAS

By Charles E. Lucke, Ph.D., M. Am. Soc. M. E.

OF the many means available for transmitting power, no one is in practice universally applied. Each has some peculiarity which renders it especially adaptable for some particular situation not possessed by the other, and is, therefore, so selected. For short distances solid transmission connections or contact pieces, such as shafts, gears or links, are almost of universal application. Greater distances bring into play successively chains, belts and ropes, the limit of which is probably the old cable street railway, the whole series forming, however, a purely mechanical means of transmitting power by the direct transmission of a force through a solid medium. It is only a short step from this mechanical transmission of a force against a resistance as a means of transmitting power to the hydraulic method of transmitting power through a transmitted liquid pressure. A liquid confined, no matter how long may be the column or complex its form, is nothing more than a rigid force transmitter, and the work that can be done by its use or the power that can be developed at the end of the system is measured by the excess of the fluid pressure over some undetermined back pressure in conjunction with the volume of fluid flowing through the system.

With the development of the air compressor in conjunction with the compressed air engine, with and without reheaters, there became available a new and more economical and flexible means for transmitting power from the compressor by the utilization not only of the excess of air pressure over the atmosphere, but also of the additional energy of expansion of this gaseous fluid, and compressed air power transmission systems have become much more common than the hydraulic, principally, but not exclusively, for small amounts of power, such as required by tools, drills, hoists and small locomotives.

During the period of evolution power transmission methods with their differentiation or adaptation to special situations, culminating in the compressed air system, electrical progress was very rapid, and electical methods of transmitting power, by reason of their great economy, adaptability and freedom of limiting distances, compared with its forerunners, enabled it to completely outshadow all these competitors. Electrical power transmission is equally feasible through only a few feet or hundreds of miles, though, of course, with somewhat unequal losses, and may convey small amounts of energy or the enormous outputs of great waterfalls without difficulty. Electrical transmission, by reason of its good features, has brought the stored energy of nature from waterfalls to industrial communities. It has likewise removed innumerable shafts and belts from our factories and shops, distributed or transmitted power of a central engine or plant to any point fixed or movable, as in cars or cranes, where work was to be done. So successful has been the applications of electrical apparatus to the transmission of power that among engineers it has come to be regarded as pre-eminently the best method of transmitting power; but no matter

how good a method a machine or piece of apparatus may be, the history of engineering progress seems to indicate that sometime and somewhere a better one will be found; if not better for all applications, certainly better for some. Engineering practice really consists in the process of differentiation, applying the principle that "what is best in one place or time will not necessarily be so in another," or that "something new may always find a useful field if essentially good."

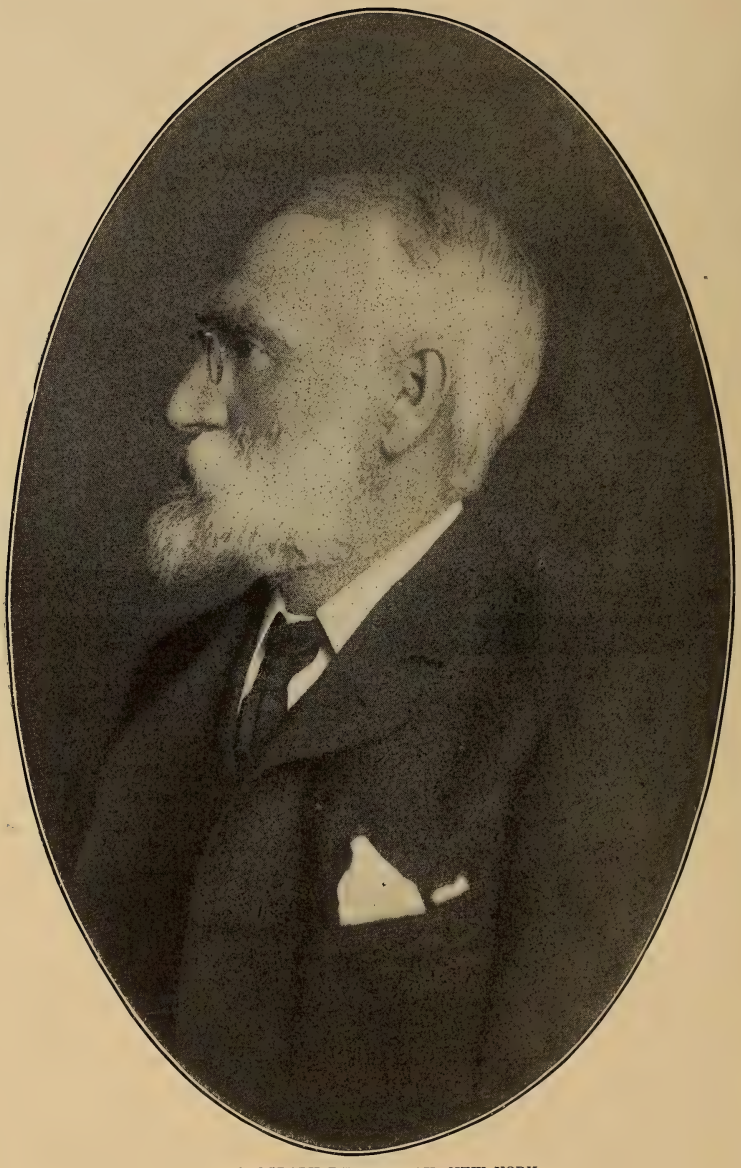
In the development of the natural-gas fields in the United States there were built very extensive pipe lines for transmitting the gas to towns and cities to be used for lighting, heating or power purposes. As the gas wells ran out and as the cities were equipped with apparatus demanding natural gas, it appeared to be more economical to seek distant wells and transmit the gas than to substitute for it anything else. Thus there have grown up in the natural gas regions long-distance transmission lines for handling natural gas, and for the sake of economy the transmission takes place at high pressure, this pressure being, in the more recent installations, generated and maintained by gas engine-driven compressors burning gas from the main line. What was intended to be a convenience for postponing the inevitable has proved to be a practical method of transmitting power not by the transmission of fluid pressure, but by the transmission of concentrated energy in the form of gas-fuel in pipes. Compressed fuel-gas may generate power precisely as dry-cylinder expansion does with compresed air; but it may also generate several times more, by its combustion in the gas engine, the exhaust heat from which would serve to reheat the compressed gas before its expansion. The comparatively limited supply of natural gas has prevented such a proposition as the above as a commercial proposition becoming a matter of general interest. As, however, the power-gas producer has, under development and improvement, become as reliable and rugged a piece of apparatus as the average boiler, requiring labour no more skillful to handle, the possibility of this method of power transmission by producer gas generated from coal is a matter that at least requires investigation.

The present method of transmitting power from the coal mine as an origin of energy involves, outside of the mine plant itself, coal-loading machinery, freight car transportation over railroad systems, coal unloaders and reloaders, and the ultimate combustion of the coal in boilers or producers. The gas producer is capable of transforming a fairly large percentage of the energy in the coal to stable fuel energy in producer gas, and the gas engine-driven compressor is capable of pumping this gas at any desired pressure through absolutely unlimited distances by means of relays of the same sort of machine along the line. The pipe line would thus become a substitute for the freight car, and might even be laid on the same right of way, and instead of delivering intermittently carloads of coal, discharge continuously into energy in the form of compressed combustible gas, this applying, however, only to so much of the coal transportation as would be required for power or heat. This pipe line could be tapped at any point for fuel gas or for power, which could be sold by meter with equal facility to both large and small consumer, just as it is at present done with electricity, and with one point decidedly in favour of the pipe line. There is practically no chance of a break in a reasonably well laid pipe line situated, for example, on the right of way of a good railroad, and service might safely be guaranteed, whereas at the present time, by reason of atmospheric condition, it is impossible to guarantee continuity of service over high-tension electrical transmission lines.

If the fuel energy in the gas under transmission be alone considered, and the possibility of obtaining work by its expansion before combustion, the weight of gas to be transmitted may be taken at almost 80 per cent. of the weight of coal per horse-power transmitted, which comparison gives directly data for comparing the cost of transmission of the gas in pipes with coal in cars. At one of the Pennsylvania mines, anthracite buckwheat, selling in New York for $2.40 per ton, is sold for 60 cents, or one-quarter as much, indicating that the cost and profits of transportation represented three times the cost of mining, and that if such gas could be piped for less than $1.80 per ton the proposition would be profitable. In transporting oil the pipe line has shown itself to be a successful competitor of the car, and the analogy suggests the possibility of working the coal mine without railroad connections at all, just as the isolated oil wells have worked. Mines too high up, too low down or too small for railroad spurs might easily install producers and feed the main railroad pipe-line, receiving compensation by meter just as the ultimate consumer pays.

Not only does the gas producer in connection with the gas engine-driven compressor offer a means of possible economical power transmission from the coal mine to the consumer, but it offers, like electricity, a similarly attractive prospect for the mill or factory having many isolated buildings, where ordinarily electric transmission will be the only thing considered. A central gas-producer plant, located convenient to the coal supply, may be arranged to furnish gas under its own blast pressure to any part of the mill where power is wanted and where it may be secured by the installation of a gas engine. The gas producer may then economically feed as many gas engines situated as close to the work as may be desired. There are many cases of group driving where this method would furnish power in just as convenient a form as electrical transmission systems, and in such cases this system will prove very much more economical, because there is a loss every time energy is transformed. In the case of electric-transmission systems the rotary motion is converted into electrical energy at the dynamo with a loss, transmitted over lines with another loss, converted back into rotary motion at the motors with another loss. The gas engine, placed at the point of group drive, may replace the group driving motor with the elimination of all other losses, and may do so in a way infinitely better than could be accomplished by steam, because there is no pipe-line loss, and because the small gas engine for each individual group drive would have practically the same thermal efficiency as a main engine driving a central dynamo. Furthermore, many manufacturing plants require heat for some of their processes, and there is no more convenient form of heating than producer gas burners. They can be controlled to maintain temperatures varying only a few degrees by means of thermostatic variations, and the gas can be the same as used for the engine.

It would appear, therefore, to be perfectly feasible to use producer gas as a means of power transmission both for short distances around factory plants or for long distances from coal mines to towns or cities, and the prospects of economical transmission are very good. It may be that practicable as such power transmission certainly is, it will not find economical application; but this possibility seems to be somewhat remote, and that such a method of transmitting power will find a place, situation or set of conditions where it can be usefully applied is almost certain.



PHOTOGRAPH BY MARCEAU, NEW YORK

Dr. JAMES DOUGLAS

PAST-PRESIDENT AMERICAN INSTITUTE OF MINING ENGINEERS

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RATIONAL TRADES INSTRUCTION

By O. M. Becker

The question of methods for providing competent workmen is one which is attracting much attention at the present time. It has formed the topic of discussion at the meetings of the large engineering societies, and the opinions concerning it are as many and diverse as the viewpoints of the observers. Mr. Becker treats of the function of the industrial school in this important department of work, and in the paper which immediately follows are given the views of Mr. Watson, a thoroughly competent engineer and machinist of the old school, so that a comparison of these two articles may well be made as elucidating some of the most practical sides of a subject of present industrial and commercial importance.—THE EDITOR.

EXISTING technical and industrial schools do little in the way of training men for those intermediate positions in productive industry which lie between the directing or supervisory engineer on the one hand, and the skilled workman on the other. They do little enough, for the matter of that, in producing skilled workers who do not rise above the position of floor man, or at most of straw boss. And the unmistakable tendency not only of technical schools properly so called, but of those purporting to be trade schools, is toward the production of engineers. Scarcely is a school founded for the purpose of training the ordinary man, than, under the leadership of a man possibly well equipped in administrative capacity but usually with a development one sided in that his view point is that of the educationist wholly and not at all that of the industrialist, it begins to shape itself into something more or less of an engineering school. Even in manual training schools, properly so-called, is this same tendency manifest. I could name a good many of the now well known engineering schools whose founders had no intention that they should ever become anything other than training schools where poor boys or girls could fit themselves for making an honest living at a good trade, and for rising somewhat in that trade. Indeed, there are comparatively few of which this might not be truly said.

The reason for this anomalous, and from an industrial view point quite absurd, tendency seems to be that an engineering school carries with it greater dignity and distinction than a mere trade or industrial school does. Furthermore, the development and teaching of the practical trades in a practical manner (something so rarely done as to be notable, indeed), is a much more difficult thing than the grinding out of engineers whose training is more of an academic and theoretical nature. It requires an insight into industrial needs and practices and a familiarity with the factory atmosphere which the mere educator rarely possesses. And it is usually an educator (occasionally a

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THE ARMSTRONG-SLATER MEMORIAL TRADES BUILDING, TUSKEGEE INSTITUTE

The schools giving instruction in boys' industries are housed in this building. This, and most of the other buildings of the Institute, were built by the students themselves

preacher) who is selected for the directorship of such an institution. Not that the methods of a technical school are necessarily unpedagogical; for the attainment of highest efficiency they should indeed base their instruction and training upon the soundest of pedagogics. The criticism I make upon most technical instruction outside engineering schools, whether of trade or mid-technical character, is that it is *not* based upon sound pedagogics.

The instructors, and the directors of the instructors, those who are responsible for the amount, nature and method of the instruction, are for the most part steeped in the atmosphere of academicism, and are unable to adapt themselves, their methods or the training they endeavor to give, to the industrial atmosphere, and to meet the needs of those preparing to enter the industrial world. I mean this: In the engineering school the laboratory method is, possibly, well enough as far as it goes. The average school man, unless indeed he is wholly out of joint with the times, seeks to apply to his technical training the methods of the science laboratory. And for students in engineering courses this is possibly enough. It gives something more than an empirical knowledge, adding to that some familiarity with theory and practice. The preparation for a trade, however, is, or should be, in view of present industrial conditions, a very different thing.

The student in the trades school is to go immediately from his school to the shop, where he comes into an atmosphere so different from that of the ordinary school that by contrast it is stifling. In the laboratory, time

and material are scarcely limited. In the shop time and material are the most important factors entering into the finished product. In a factory a thing must be made expeditiously and without waste of material. If unable to conform with these conditions the embryo industrialist fails to get a foothold and inevitably sinks to a lower class of work where efficiency counts for less. It is thus obviously a function and a duty of the trade school to give its graduates not only a working knowledge of the machines he will be called upon to use, and to develop a modicum of skill in its manipulation, but to develop habits of

HACKLEY MANUAL TRAINING SCHOOL, MUSKEGON, MICHIGAN

This school, founded by the wealthy philanthropist whose name it bears and by him presented to his city, is probably the best equipped of its kind in the United States

work which will make it easy for him to fall in with the customs and practices in work shops.

It seems to me that a trade school which permits its students to go away without having acquired these habits and without having become really proficient and efficient, misses far the mark. Whatever may have been the recognized end or purpose of industrial schools heretofore, there are unmistakable indications (with which, however, the average school man, and captain of industry as well, seems strangely unacquainted), that the industrial education of the very near future must be adjusted to modern conditions; must be based firmly upon the new and broad definition of education already accepted by all who are alive to the new order of things; must, in fact, prepare youth not for beginning to learn how to earn a living, but actually how to earn it, and to do it with a high efficiency. Yes, more than that. The trade school particularly, since it purports to prepare youth for their real business in life, must break loose from academicism and readjust its instruction and practice so as to be able to send forth the youth equipped with skill and knowledge; yes, but also possessed with the habits and notions prevalent in the factory shops upon which he has his eyes fixed. It must, in fact, be a place, not where youth are being prepared for life, but where they actually are living, in some degree anyway, the life to which they are looking forward; where the atmosphere is possibly not exactly that of the shop, but certainly not that of the ordinary school—rather a mixture or transition from this to that. This means among other things that the student is responsible for his work, and that he is not beginning, but actually engaged in making a living (in part at least) by producing something that other people want enough to buy for good money. True, such a basis for trades education would upset the yet current dogma that education is only a preparation for living, and would revolutionize things completely. That, however, is just what seems to me essential to bring industrial education

PRIVATE TRADE SCHOOL OF R HOE & CO., NEW YORK

A demonstration of the mathematics of lathe gearing. This school is about thirty-five years old, and is conducted on the premises of the Company especially for its employees

ANOTHER PRIVATE TRADE SCHOOL, AT THE WORKS OF THE NATIONAL CASH REGISTER COMPANY, DAYTON, OHIO

into harmony with the times. And this basis is not merely theoretical; it is the foundation stone of at least two schools, one of which has been in successful existence for many years.

Not that the trade school graduate, in the trades involving a wide range of knowledge and skill at any rate, should be a full-fledged journeyman competent to earn the maximum wage. No doubt this is possible in rare instances of exceptional ability; but in general even four years of practice in all the several kinds of work of, say, the machinist's trade, for example, is insufficient to develop the skill and speed that comes only with years of experience. But the trade school can and must give sufficient instruction and practice in the trades and their ancilliary arts and sciences to make the student actually proficient; and withal give the necessary instruction in the academic subjects whose apprehension is essential to a proper understanding and practice of the particular trade. But above all it must inculcate in the student correct habits of work, give him some familiarity with actual industrial conditions and methods, and imbue him with a sense of the dignity of his work and the possibilities which it contains for him as well as for society at large.

POURING OFF, FOUNDRY OF WINONA TECHNICAL INSTITUTE, INDIANAPOLIS

This department was opened a year or so ago, and is conducted on approximately a business basis. The students are paid a weekly wage, and the school sells the castings, having a demand in excess of the output most of the time

The development of some skill almost any trade school can secure, and all that may fairly be so called do secure it. The teaching of the correlated academic subjects most of them do with more or less success—often less, because the instruction often is purely academic or abstract instead of being so far as possible a series of concrete illustrations of the work the journeyman will be called

FOUNDRY IN THE HACKLEY MANUAL TRAINING SCHOOL, MUSKEGON, MICHIGAN

The instruction in schools of this sort could easily be extended so as to cover the essentials in the trades. They would thus become real industrial schools as well as schools for culture

upon to do. As for the third essential to satisfactory trade instruction, that which affects the attitude of a man, his efficiency, his relation to the industrial system and to society; these things American industrial schools, no matter how designated, with a few possible exceptions, neither do, nor apparently attempt. The controlling interests in nearly all of them seem for the most part wholly unaware that any such needs exist, or that the embryo industrialist who comes to them has a right to something more important than the ability to operate a lathe or to read a drawing intelligently.

It is high time our educators were waking up to the needs, yes, to the demands of the present situation. It has been remarked that educational systems are always at least a generation behind existing needs at any given time. Perhaps it is so. Certainly our present educational program has not been brought anywhere near a harmonious adjustment to the requirements of our youth whose eyes are fixed upon an industrial career. A few school men have been aware that something is out of joint; and fewer still have a suspicion as to the direction in which the difficulty lies. The very few that have been not only educators but also industrialists, or at any rate have been in such close touch with industrialism as to have breathed its atmosphere long enough to see things from the view point of the worker and his employer, as well as from that of the educationist, and is therefore competent to judge advisedly; these know certainly that it is our woeful lack of industrial schools, and the unfortunate nonapprehension of existing conditions by many of those that do exist, that put things so sadly out of joint.

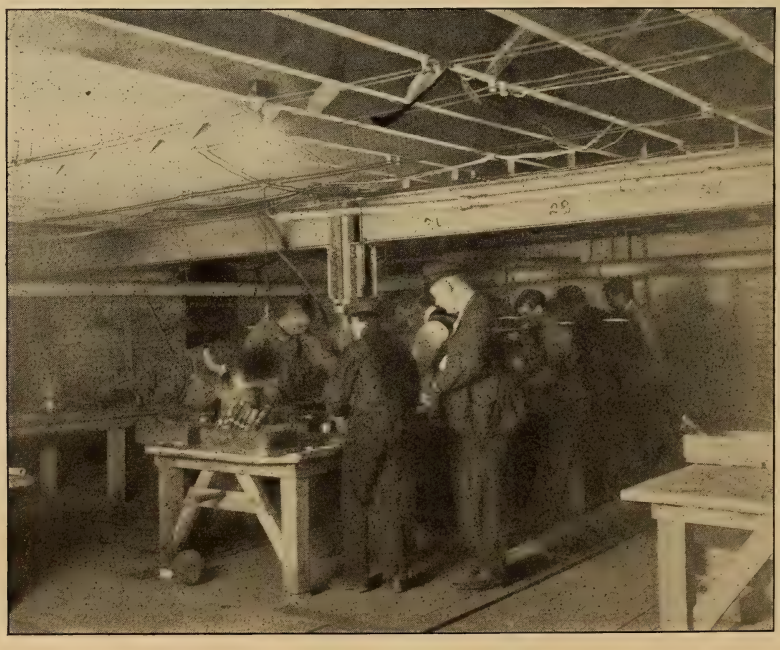
Manual training schools, popularly so called, of course have an end chiefly cultural. The training in handiwork given in them, and in other industrial schools of similar purpose, though possibly differently designated, is such as may incidentally develop some skill; but it's purpose is rather to develop a side of the student's nature which is not reached through the academic subjects, and the lack of which would leave him more or less lop-sided and unbalanced, something less than an evenly developed and cultured man. The exercises are therefore more or less play-work; or if not this, then (from the very nature and end of such a school) the training covers but a very small part of any given kind of work, stopping far short of what would be necessary to develop more than a modicum of skill and knowledge of a trade by which the student might gain a livelihood. There are a good many (speaking with respect to the whole number of industrial schools) institutions which limit themselves to the field properly belonging to the manual training school, but which could just as well (had the management a broad enough vision and an adequate apprehension of the nature of the present problem) set themselves to the much harder but more necessary task of teaching those who come to them the complete modus operandi of making a living in some particular line of work. This applies as well, perhaps, with greater force, even to institutions having charge of delinquents or dependents. Turning youth of these classes out upon the world with a smattering of something, but practical knowledge of and satisfactory skill in not much of any-

TIN SHOP, TUSKEGEE INSTITUTE

This school was started and is still under the directorship of Booker Washington, who takes pride in his rise from slavery. It is doing a wonderful work in training negro youth in the arts of making an honest living

thing; that is to say, without a preparation which gives reasonable assurance of ability to make a satisfactory living in some line of work or other, seems to me a very great wrong, not only to the youth, but to society.

There can be no objection to schools for culture, as such. They have not that exclusive position in modern civilization which they formerly held; but nobody (except perhaps Mr. Crane, Mr. Hubbard and possibly a few others) but admits their value as mind developers. The college man beyond any question, other things approximately equal, has a great advantage over the non-college man, not only in his enjoyment of life, but in his capacity as a business man or industrial worker. Nevertheless, the higher culture, the college, even the high school, is for the few. Some day, let it be hoped in the near future, conditions will have been changed so as to permit and require all to receive the benefits of the culture obtainable in a high school, at least. For those wishing to enter industrial life, or business, or any special line of work, as all should, the courses will be adjusted so as to lead directly into the trade or business school for which it has prepared the student. This obviously means a revolution, perhaps it were better to say a reformation, in high-school and perhaps college ideals, curricula and pedagogics. There is not wanting evidence that the reformation is already in progress. Witness the development of manual training and technical high, and schools of similar names. They are feeling the way, and that is encouraging. If now those those in authority could be induced to take counsel with those who have studied the problem at first hand and from all points of view, no doubt there would be an immediate and tremendous advance toward the establishment of a rational system of industrial education, a system adapted

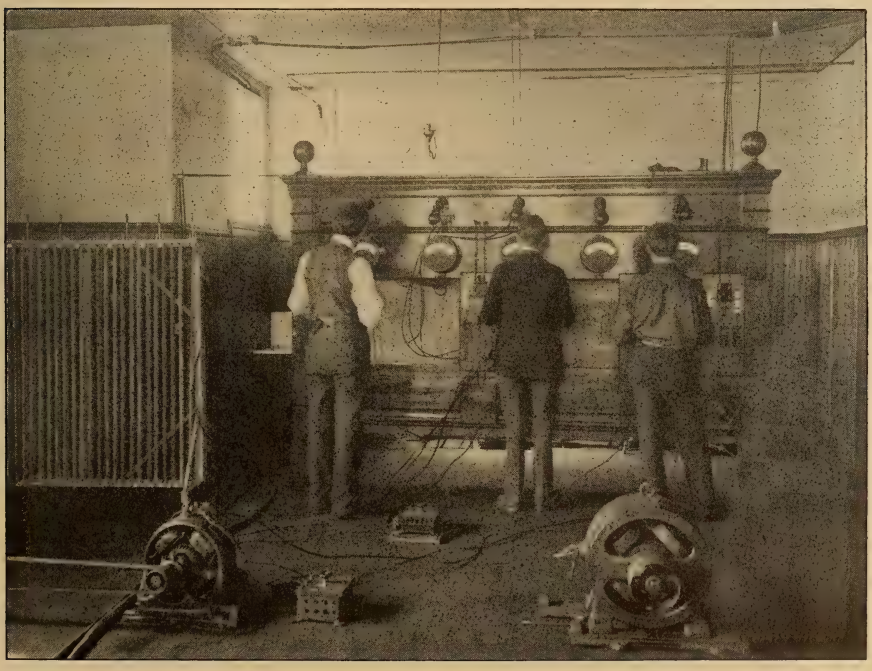


PLUMBING DEPARTMENT, MILWAUKEE SCHOOL OF TRADES

This school was started some two years ago under the auspices of the Merchants' and Manufacturers' Association of Milwaukee and has recently been taken over by the Board of Education under the provisions of the law passed last winter permitting cities to maintain trades schools

GENERAL ELECTRIC COMPANY, WEST LYNN, MASSACHUSETTS, WORKS

Apprentices of the General Electric Company, Schenectady, New York., in the pattern shop. This company maintains at its Lynn (Massachusetts) works a regular apprentice school



CASINO TECHNICAL NIGHT SCHOOL

Apprentices of the Westinghouse Companies (Pittsburg) in the electrical testing laboratory of the Casino Technical Night School, a sort of trades school maintained by these Companies for their apprentices and other employees

CHICAGO TELEPHONE COMPANY

Telephone companies generally train their new operators. This is a school-room of this kind in the school for operators conducted by the Chicago Telephone Company

to the existing conditions and not dominated by ideals no longer consonant with the present status of civilization.

But that is the very thing those in authority will *not* do. I have always said that many new industrial schools are turned over to men who have made names as college presidents or as preachers—or possibly as politicians. The men usually at the head of trades and other industrial schools are imbued with the ideals of the university president. They have not gotten away from the atmosphere of academicism in which they were bred. No college or normal school head will for a moment consider, for an instructor's position, any one who has not the proper labels and tags signifying that he has for such and such a time been an inmate of an approved institution of learning. No matter how much practical experience a man may have had, how cultured he may be, how thoroughly well he understands his subject; unless he is properly labeled he is told to stand aside and the novice freshly liberated, but bearing the proper earmarks, though wholly without practical experience, is invited to enter. This is not an occasional occurrence; it is the all but invariable practice in schools of culture. And it is the practice to a scarcely less degree in engineering, and technical, and trades, and in all other industrial schools. No label, no job as instructor.

Of course this results in filling these schools with teachers possibly well qualified in most respects, but, as already pointed out, certainly not possessed of practical experience such as would qualify them to be first-class journeymen. It is a pedagogical maxim, almost an axiom, that one cannot teach others that of which he is himself ignorant. It would seem obvious,

COMPOSING ROOM, JOB PRINTING DEPARTMENT OF THE WINONA TECHNICAL INSTITUTE AT INDIANAPOLIS

The job work done in this shop is commercial in one sense—it does all the printing for the school and for the Winona Assembly, and for other affiliated institutions. The boys receive no wages however, as they do in the foundry and machine departments of the same school. Several of its departments are equipped and partly maintained by the national organizations of employers interested in those particular trades

therefore, that a teacher preparing boys to become journeymen, should have at least as much skill and practical knowledge, and besides have such an apprehension of industrial conditions, as he is to obtain in the boys. In some trades schools an effort is earnestly made to secure instructors fulfilling these requirements, and the lack of a diploma or other distinguishing label is not very seriously regarded. Indeed many journeymen, without any higher training than that secured in the elementary schools and in an apprenticeship, but showing an aptitude for instructing and influencing youth, have been selected for such positions with eminently satisfactory results. It by no means follows that any journeyman could become a good instructor; most of them, indeed, have small ability as such, even though possessed of the highest skill as workmen. There is much truth in the old pedagogical saw that a teacher is born, not made. He must have the inherent liking and adaptability. If merely made, lacking these things, the job of making is likely to be a very poor one. And this holds just as true of college and engineering school graduates as it does of other persons.

Given an aptitude for such instruction, for getting next to his pupils, he is clearly the best prepared instructor who has added to a thorough mental and theoretical equipment and a broad view obtained through contact with the atmosphere of higher institutions for culture or for technical training, or both, a suitable experience as workman in the trade he expects to teach. The same thing is true as to teachers in the higher technical and engineering schools. A mere theoretical knowledge of shop work, for example, is a very different thing from the knowledge gained by experience; and it is therefore not surprising that youth are so often sent out with ideas and habits which they quickly find on entering actual work to be impractical, inefficient, even laughable. But the instructor with this equipment is rara avis; and when found, his earning capacity sooner or later is rec-

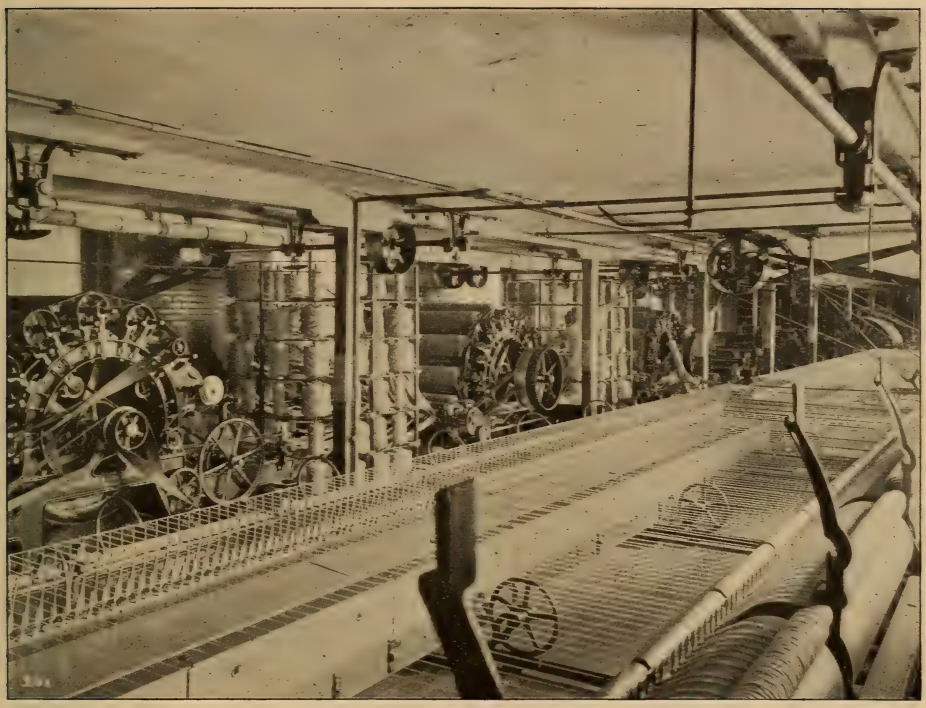
ognized and an opportunity for remuneration more nearly commensurate with his experience and ability takes him out of the ranks and into the field of productive industry; unless, indeed, as sometimes happens, there is in him an abiding and transcendent love for teaching.

As to that other class of instructors, usually non grata to directors of industrial schools, those who have had a large practical experience in their line of work, coupled with good sense and a moderate amount of school training; they are by no means too numerous. There is a need for many such in our industrial schools, just as there is of those with high technical training, as already described. But of instructors qualified in both these ways there is a lamentable dearth, when the whole number of instructors in trades and other industrial schools is considered.

In certain quarters the professional teacher is not favorably regarded, just as in others the non-college man receives the cold shoulder. There is at least one regular school in this country, besides several others conducted by manufacturing concerns for their own employees and apprentices, where practically all the instruction is given by men actually engaged in the business or trade which they teach, and who not infrequently never had any previous teaching experience. In this particular school the students work side by side with journeymen, and learn from them; their work is not mere play-work, but they make a salable product, and earn a living, or something that goes toward making a living, while learning. Theory goes hand in hand with practice, in the applied portions of the course, at any rate. This school is conducted by a man who is himself a manufacturer of large interests, and who was for years an instructor in an engineering school of high rank. The scheme is so rational, and its several features have been so successfully worked out separately in one place or another, that it ought to have been applied to

NEW YORK PREPARATORY TRADE SCHOOL

Something different is the New York Preparatory Trade School, conducted by Mr. Ellery Sedgwick H Ftakes in boys from the street (and girls also) and starts them well on the way toward the acquisition of trades. Only young people not able to enter the regular trade schools are taken. The picture shows a class in carpentry making their drawings



WOOL CARDING AND SPINNING ROOM, TEXTILE DEPARTMENT, PENNSYLVANIA MUSEUM AND SCHOOL OF INDUSTRIAL ART

This was the first textile school in America. It is rather more than a trade school and is the model for most of the other textile schools in the United States

industrial education these many years. It seems to me astonishing that it has not been generally adopted. The director of this school is by no means the only, and possibly is not even the first, to work out a really rational scheme of trades instruction; but apparently he is the first to organize a trade school on these lines outside of one, or possibly two, privately conducted in manufacturing establishments. And so far as is apparent, there is but one lone school ready to follow the same lines, and that is as yet on paper only.

As might be supposed, the atmosphere of this school is very different from that of many other trades schools. It is notable also for another thing. Students finish their courses as soon as declared by their instructors to be proficient. There is no marking time, in order to fill out a specified number of years, but a continuous forward march to the end sought—proficiency. As most instructors in trades schools are well aware, one of the most difficult problems is to keep the youth until the end of a course, which presumably means until the required knowledge and skill has been acquired. The diploma next year means less than the job to-morrow. It is a manifestation of the dollar fever, with which Young America is dangerously affected, scarcely less so than his father. In most other schools the students leave anyway, as a general thing, if they feel assured that they have acquired proficiency; and that is nearly always before they are really competent. But this choice, unfortunate in the long run for the one who makes it and for his employers, is made nearly always upon the direct or indirect solicitation of some employer. It is a sad reflection upon

his perspicuity, to say nothing of the wrong he does to the youth thus lured, as one may say, from a complete preparation for efficient service and efficient living. But the fact is unquestionable, that as soon as a trades school student becomes a half-baked workman, so to speak, he is almost waylaid, overwhelmed and seduced with offers of jobs at wages that seem high to him, but which in fact usually are considerably less than those paid to the skilled workman whom more than likely he is expected to displace.

Handicapped by this condition, and by the many others well known to those connected with schools of this sort, it is indeed of the highest importance that trades schools have a sound and rational basis for the instruction offered. This basis, it seems to me, is to be found in a close adaptation of their methods of actual practice, the development of an atmosphere strongly impregnated, if not saturated, with the industrial spirit, and the working out of some practical scheme whereby students can become wholly or mainly self-supporting while learning a trade. In spite of all, or rather of most, past experience, I am confident that a school so based, and conducted in this spirit would become self-supporting also—provided, of course, the equipment is already to hand.

But:

An industrial school may be all these things, and still fail in one important, yes, in an essential mission. Above all things in a teacher, and likewise above all things in a school, is the moving spirit. So far no mention has been made of instruction other than that having to do with productive work. The industrial school, however, if it is to justify itself completely, must not fail to carry further the work of the elementary school in training for citizenship. Possibly it may not be the province of these schools to devote themselves specifically to the inculcation of good citizenship. As a matter of fact, the training of proficient and conscientious workmen is in itself an indirect training in that direction. But the school which limits itself to this only, which does not through its teaching force inspire to moral uprightness and consequently to a high civic sense, misses a wonderful opportunity. Such teaching, such inspiration, may perhaps not be formally announced upon the program; though no doubt formal instruction might be desirable. Chiefly it comes from the personality, the vital indwelling spirit of the teacher. For there also may be Gamaliels whose themes are homely and practical, at whose feet work-a-day Pauls may sit and receive inspiration.

APPENDIX.

Several years ago the following prospectus was prepared for a school of trades and crafts, to be located in Chicago. As will be seen, it proposes to carry into practice a plan of organization and scheme of instruction essentially the same as that indicated in the preceding pages. Much interest was aroused, and the plan was generally approved as practicable. But Chicago seems not an encouraging field for the establishment of a trades school. And there is not now anything that could be properly called a trades school in the second city of America.

A SCHOOL OF TRADES AND CRAFTS TO BE SITUATED IN CHICAGO

OBJECT.

To provide a school for practical instruction in the several trades and their allied crafts, under conditions closely approximating those prevailing in the average commercial shop. Graduates of the school will have received a training at least equivalent to that formerly required of apprentices in the trades, and such academic instruction as may be found necessary or useful in the practice of their trades. The disadvantages of

the apprenticeship system are to be minimized.

PLAN.

Close relations are to be established with representative manufacturing concerns with a view to doing for them such typical work at the prevailing price as may be found suited to the needs of the school. It is probable that a considerable part of the work of training might be done in the shops of such manufacturing plants, thus getting not only approximately, but actually, the practical shop conditions for the students. The school would therefore be, contrary to the usual practice, not a school with a shop attachment, but a shop with a school attachment. The shop work would be done primarily for instruction, and secondarily for profit, thus bringing the apprentice at once into the industrial competition of which he will later become a part.

CURRICULUM.

The trades at first offered would of course be limited, and might include Machinery, Iron Molding and Founding, Patternmaking, Carpentry, Cabinetmaking, Housekeeping (including the ancillary occupations of Sewing, Laundering, Cooking, and the like), and perhaps certain of the building trades. As the school developed, other courses would be added until the local needs were being supplied.

ADMISSION.

This would be esentially a school for poor boys and girls, and should therefore provide for taking care of even the least qualified. A grammar school education would be presupposed, but any such deficiency could be made up in the school. Furthermore, along with the trades courses would be parallel courses more or less academic, such as are necessary to a thorough mastery of the trades.

FEES.

The quesion of fees is not essential. Fees, perhaps nominal, should be charged. As the school would be on a commercial basis, this would not limit its usefulness. The students, since they would be doing commercial work, would receive the prevalent pay, this depending upon their own industry and skill, and would thus become practically self-sustaining.

SUPPORT.

Given a suitable plant and equipment, such a school should after four or five years become largely, if not wholly, self-sustaining. By plant is meant not merely school shops, but a commercial shop or aggregation of shops.

WHY GOOD WORKMEN ARE SCARCE

By Egbert P. Watson

THE scarcity of good workmen is universally admitted, not only in the metal trades, but in all branches of manual labour; the reason for this is found in the methods practiced by manufacturers in many lines, a majority I might say without exaggeration; the versatile tradesman, who can be trusted to complete any given piece of work from plans given him, has passed away, crowded out by the operator of an automatic machine of one sort or another. Young men do not learn trades nowadays because there is no incentive for them to do so. Fifty years ago they did, for the reason that automatic machines did not exist to any great extent, and men depended upon their skill and dexterity in handling tools, at which they were extraordinarily expert, but with the result of making the work executed cost much more. I said above that young men do not learn trades, as a rule, now, for they can make more money in much less time by taking up a handicraft, machine operating, for a calling.

In a large city near New York there are many factories, employing thousands of young men who operate machines exclusively. They are what are called "handy men," that is, merely machine tenders, who have learned how to place stock in presses, punches, or what not, continuously. After a little while they become expert at it, and being paid by the piece, can earn good wages as unskilled labourers, say, $5 or $6 per week; with still more familiarity they can get $7 to $12 per week. That is about the limit, but it suffices them, for on the sum named they marry young women of their own station, become householders and beget the proletariat of the future. A large proportion of these young people are foreigners, who have been in the United States a few months at the most, Hungarians, Poles, Croats, etc., who understand how to support life upon fare that the vagrom American dog would spurn, and the money they get enables them to bring others of their kind to this country, which they speedily do. While the majority of these workers are of foreign birth, there are not wanting Americans among them who, from one cause or another, dislike to serve apprenticeships and gravitate to the ranks of handy men. The timekeeper of one of the factories in question told me that at least 75 per cent. of the employed were mere operators, who could not perform the slightest readjustment of the machine itself in case the work was not properly done or would not pass inspection. Indeed, they were not permitted to do so; the faulty machine was thrown out of use until the repair man came around. The sole function of the attendant was to put the stock—iron or brass—in a certain place, when the machine did the rest. It will be readily seen that this requires no manual dexterity, no long apprenticeship to be served in order to make a living. Men past middle age who have worked at all callings can be found in this place, glad to earn anything at all in the short time remaining to them before "they go hence and are seen no more." Ambitious young men who desire to rise in the world and be something more than hewers of wood and drawers of

water, do not waste their time as handy men, but it requires more than mere ambition to serve an apprenticeship until the stipulated time for it has expired. Money is needed for support, which relatives must supply, the small wages paid being quite inadequate for food, shelter and clothing through four years unless in unusual cases. I know of one concern that pays its apprentices $9 per week during the last year of service, and even then there are the three previous years during which small wages have been paid and that some one else has to account for. Local young men take all these things into consideration, and in a majority of cases select places where they can get paid while learning, regardless of the fact that at the end, or final reckoning, they are just where they started, having no trade. I have not mentioned the deterring influence of trade unions upon the supply of mechanics, but it is a factor to be reckoned with. Suppose a young man has learned a trade and secured employment at good wages; in steps the union and demands an exorbitant admission fee for the right to work in the town, and their protection, against what foe?

The causes just mentioned tend to restrict the supply of skilled workmen. Possibly not mechanics, because that term has a wider significance than manual dexterity only implies, but it reduces the available material to be had from which workmen could be made. If we multiply the city near New York mentioned previously by many others nearly all over the United States, we shall find that the young men who are not learning trades are in vast numbers, Aside from mere operators, there is another disturbing element—an avocation only, not even a handicraft—which absorbs thousands of young men, who live from hand to mouth, liable to be dismissed at a moment's notice, and left with what may be in their pockets; this class is made up of trolley-men, conductors and drivers. None of them produces anything which can be sold for money, except their ephemeral knowledge of which way to turn a lever to stop or start a car. They own no taxable property, save a few small holdings in the way of furniture, and from that point of view are burdens upon the community at large, but they are units in the large army of men who should be learning trades of some kind; while possibly they would never be mechanics, they could at least be the rank and file, in which honourable regiment they could do the world at large some service. No man who works according to his natural ability can be considered as of no importance. But men who comprehend nothing that they cannot see with their eyes or touch with their hands are merely blind workers, subservient to and auxiliaries of those who use both hands and brain.

That many employers are alive to the situation is shown by the fact that they have inaugurated trade schools in some parts of the country, which are a part of the apprenticeship system, and give young men in their shops an opportunity to learn what their brains are for, if nothing else. In itself this is great gain; thereafter their advance depends upon their ability to absorb what is set before them. Hand in hand with this go the mechanical operations, commercial work, not mere mechanical kindergarten exercises, which only familiarize young men with the names and aspects of tools, so that after a certain time has elapsed student apprentices will become valuable in the special line they have taken up, but they will still require actual experience outside before they can stand upon their own mechanical feet. The student-mechanic has not had the stimulus of competition to bring out the best that is in him. Neither has he had the fear of being summarily discharged for faulty work, the bitterest drop in the cup the expert has to drink from. I can recall to this day a few incidents of

this kind which happened to me over forty years ago, and live over again the humiliation I felt because of forgetfulness, or misconstruction of dimensions, by reason of not concentrating my mind on what I was doing, resulting in no serious loss to the shop, but chagrin unspeakable to myself.

I hope I shall not be accused of dwelling too much upon this aspect of the workshop trade school, but it seems to me that it is an important point to consider. In so far as I understand the intention of those who manage the shops wherein at least elementary instruction in physics is given, they desire to get a better class of men for their own use solely, not at all to supply the world with superior workmen. They could not do that, for the demand is too great; only a certain number can graduate, so to speak, from the workshop trade school—hundreds let me say in lieu of the thousands that will be called for—and the graduates by no means intend to follow the trade, or trades, for a steady business; they do not rate in the life class, but do acquire a better general knowledge of the trade than they would have by acting as ordinary apprentices. Thereafter they intend to obtain better positions and get more salary than a shop worker.

They are inchoate mechanics, to be developed with time and chance into men who can overlook contracts and carry on engineering trade successfully. They rank with young lawyers, physicians, musicians and professional men generally, who have to be seasoned by experience before they develop the best that is in them. It takes, also, a long time to make a skilled workman, so that neither class has an advantage at present as modern engineering work is carried on. On the one hand the old time workman is still in demand for his knowledge of the possibilities in any given case—for producing work rapidly and accurately by new machines and processes; on the other hand, he is a stumbling block from his ante-bellum prejudices against change. A curious situation, indeed; to harmonize the various discrepancies in it and remove them, to the end that both economic and industrial benefit may accrue, will be accomplished slowly; just when, I decline to make any forecast.

MECHANICAL STOKING ON LOCOMOTIVES AND MARINE BOILERS

By C. S. Vesey-Brown, M. Inst. C. E.

One of the noticeable features in the design of recent prime movers is the increasing size of the units. This is apparent, not only in the case of stationary installations, but especially in connection with locomotives and steamships. In both of these classes of machinery there is one element which has not progressed as effectively as the other parts of the apparatus. In both cases the coal is still delivered to the furnaces by hand. Various efforts have been made to replace this difficult manual labor by mechanical appliances and Mr. Vesey-Brown discusses some of the latest methods of accomplishing this most desirable end.—THE EDITOR.

THE problems connected with fuel consumption on all steam generating plants, have occupied the minds and taxed the ingenuity of every physicist and engineer since the days of Hero.

To reproduce as many of the heat units put into steam by either coal, oil or gaseous fuel is the aim of steam engine makers, and this is more particularly the case with those who are connected with the transition of men and matter from place to place on this busy sphere.

The locomotive and marine superintendents of the railways and steamships throughout the world look, first and foremost, at the "coal bill" of each new type of locomotive, or of a sea voyage from port to port. Every inventor who has a new system of reducing the fuel bill is given every opportunity of showing what he can do. Here it is a new economizer, and there a special type of superheater, or the position and size of the grate is so altered as to burn a lower grade of fuel, special doors for opening and shutting quickly to prevent inrush of cold air, or, again, the entering air is heated by the waste gases in the smoke stack, etc. Innumerable are the devices for reducing the fuel bill, but the same human stoker is employed in all cases. Very small attention has been paid to the use of mechanical means of coal firing, and in these days of labour-saving devices and the better methods put into the hands of the workman to save him that arduous labour which is repugnant to the human senses, it is surprising what little progress has been made in this direction.

It was thought at one time that oil fuel would prove the solution, but, in spite of the practice of men like Mr. James Holden, of the Great Eastern Railway Company, and Mr. Urquhart, of Baku fame, oil fuel for locomotive and marine boilers has made little progress in those countries where coal is plentiful and cheap. We have seen, moreover, in the last twelve months, an abnormal activity in the world's trade; exports and imports have everywhere increased enormously, but with it all the one "fly in the ointment" has been the increase in the price of coal. With such a condition of things before us, it is not surprising that the attention of those immediately connected with the locomotive and marine traffic should be directed with more searching investigations into the coal and fuel handling of the steam plant under their supervision.

Taking first the case of the locomotive, it will be remembered that in the May number of this magazine an article on the subject was contributed by Mr. G. L. Fowler. The article attracted so much attention that it was decided to enlarge the

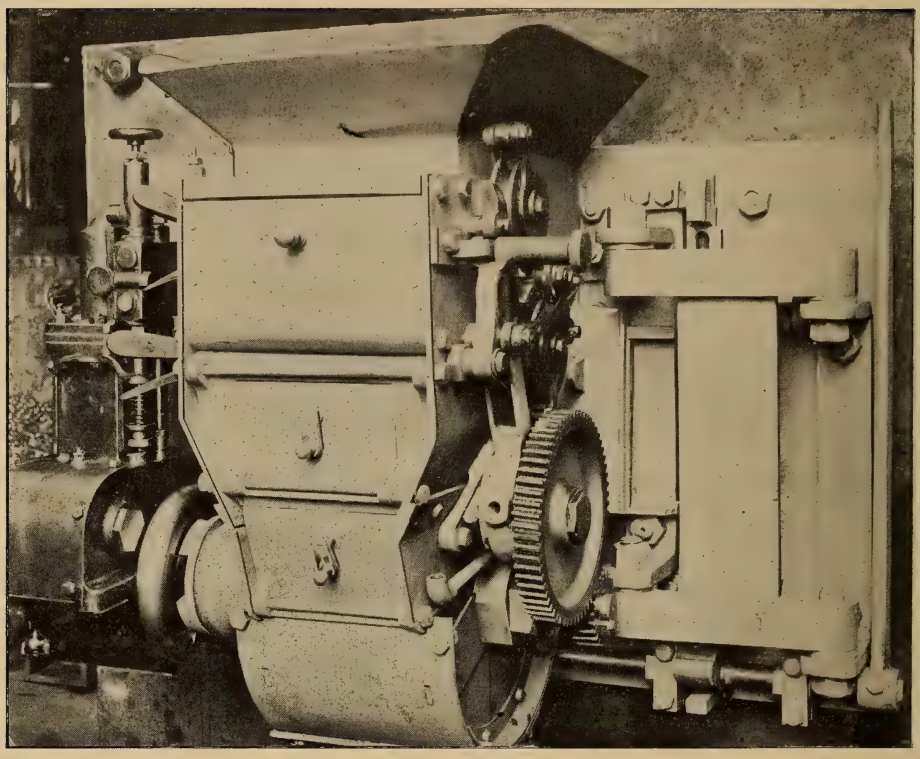


FIG. 1.—FRONT VIEW OF STOKER, SHOWING HINGED DOORS, GEARING AND ENGINE. THE ECONOMIC STOKER COMPANY, LONDON

scope of the subject, and with that end in view the present article is written.

In the first place, it is a surprising fact that very little information is available as to the coal used for "steaming" on railways and steamships. The English Government do their best to keep a fatherly eye on this matter as far as it is possible to do so, and as a result of returns made by railway companies and coal shippers in the United Kingdom it is found that 11,593,758 tons of coal were used on the railways in the United Kingdom in 1905, and that 18,590,213 tons of coal were shipped from ports in the United Kingdom in 1906 for "ships' use on foreign voyages." These latter figures take no account of the coasting trade, and it is impossible to elucidate any facts as to what proportion of the exports of coal other than the above items would be used for locomotive and marine purposes. The exports of coal from the different countries from which particulars have been obtained are as follows for the year 1905:

	Tons.
United Kingdom....	47,476,707
United States.....	9,019,870
Germany	17,865,189
British India.....	837,000
Australia	2,026,000

These figures in themselves convey very little as to what the exported coal is used for, but it is certain that a considerable portion is used for "traffic" purposes.

Reverting to Mr. Fowler's article, he therein describes, fairly accurately, the lines upon which such an apparatus as is required for locomotives should be designed to operate. The conditions he lays down as essential in an efficient stoker are, shortly:

1. The device is to be very compact, on account of the limited space

at the disposal of the locomotive engineer, and to leave ample room for the engine crew.

2. In the event of failure of the apparatus, it should be easily put out of commission and allow of immediate hand firing, and so prevent any delay in the traffic.

3. Any class of fuel should be capable of being dealt with, and the rate of burning same or feeding it into the firebox should be easily controlled.

There are other minor points, such as economy, easy access to the firebox or tubes and tube plate, simplicity of action, and the necessity of the apparatus being self-contained, which are all details patent to every one concerned in this most important subject.

A point which was not mentioned in the article is the question of weight of apparatus, and this applies with equal force for either locomotive or marine boilers. Generally speaking, all the conditions which are specified, together with the question of weight, apply to marine boilers.

In the article are described two patterns of stokers which have been used in the United States, and, in a very small degree, in Europe.

With the object of carrying the subject a stage further, it may not be out of place to describe a method which, as far as can be judged by present experience, fulfils all the requirements laid down by Mr. Fowler, and generally such other conditions as may be called for by either the locomotive or marine superintendent. The description given here applies more particularly to locomotives.

The economic stoker which is illustrated in Figs. 1 to 6 operates on a novel principle.

It is essentially composed of five parts:

(1) A hopper.

(2) A coal crusher to reduce large coal to convenient size to obtain com-

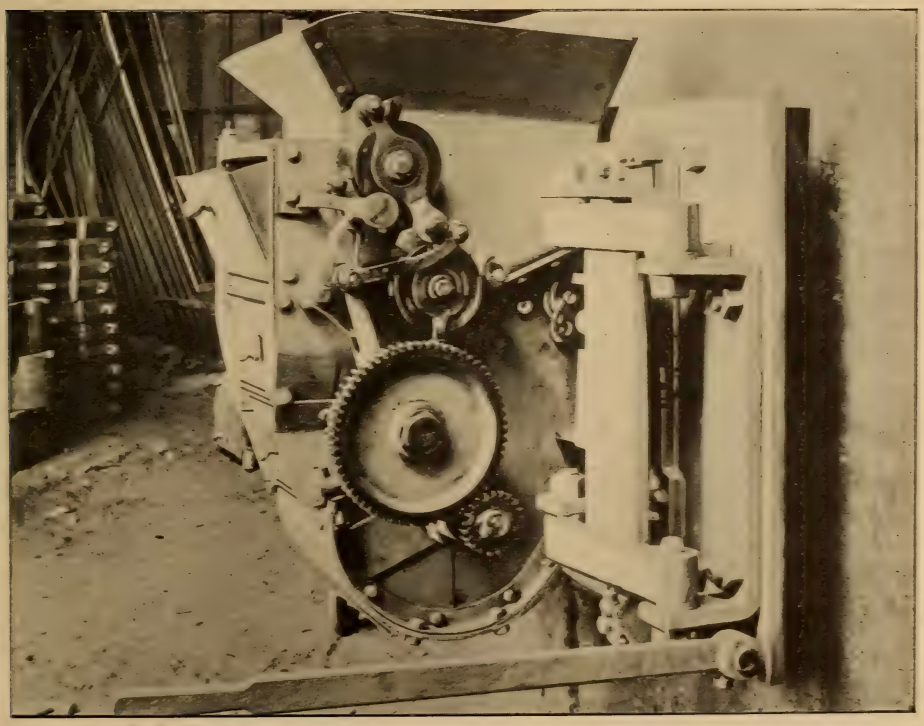


FIG. 2.—SIDE VIEW, SHOWING FRICTION GEARING FOR CRUSHING ROLLERS AND GEARING FOR REVOLVING FAN

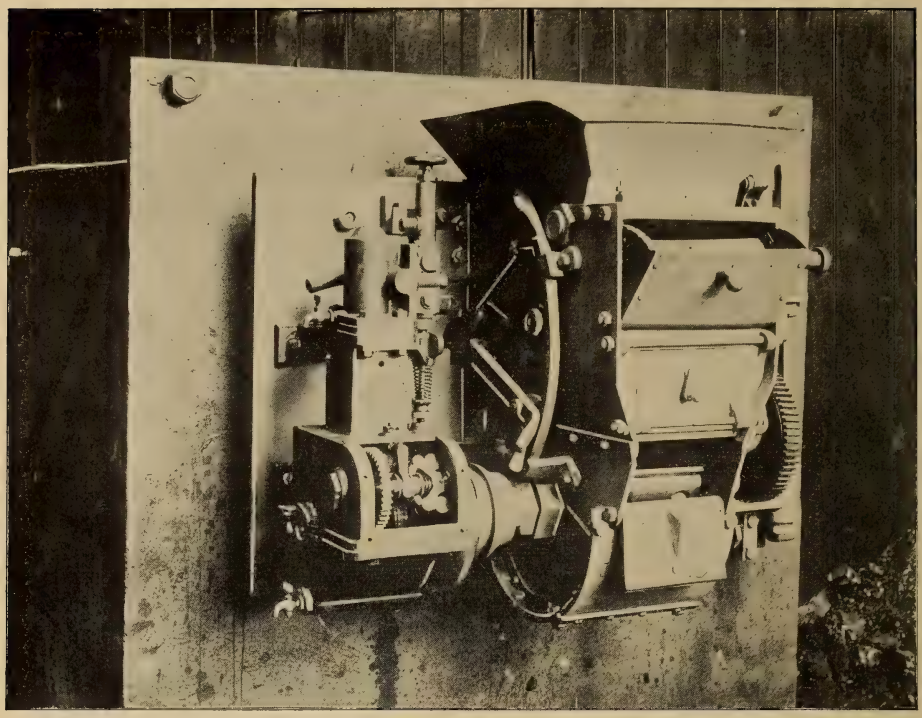


FIG. 3.—PERSPECTIVE VIEW OF STOKER, SHOWING SPY HOLE DOORS, ENGINE, AND SHOVEL HANDLES

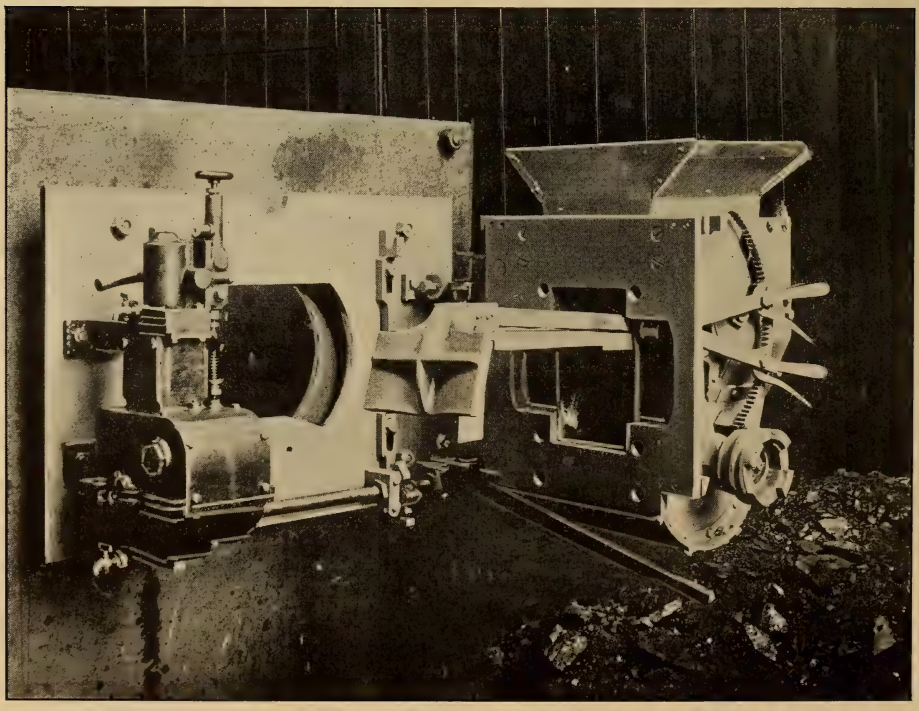


FIG. 4.—STOKER SWUNG GLEAR OF FIRE-BOX OPENING

plete and economical combustion.

(3) A revolving two-blade fan or "thrower."

(4) Two deflecting plates to spread the coal over the surface of the fire, as required.

(5) The prime mover required to operate the mechanism.

The hopper may be of any convenient size, according to the size of the locomotive cab in which the machine is installed.

The coal crusher consists of a pair of rollers which are operated by reciprocating friction gear actuated from the shaft of the prime mover. The crushed coal falls on the two-bladed revolving fan, shutter or "thrower" (whichever term is used), and is projected forward into the firebox and distributed as required by means of one or both of the deflecting plates. These deflecting plates are so arranged that on the upper one, or "cap," being raised or lowered, as the case requires, so will the coal be "shot" to the far end of the fire grate or deflected to the inside of the grate nearest to the firebox door. It will be noticed that the two lower corners of the rectangular deflecting plate, or "cap," are cut away, and this arrangement allows the coal to be distributed along the sides of the grate. The operation of the two deflecting plates by means of the two handles held in place by the ratchets determines the density of the fire throughout its length and width.

It will be seen that the whole apparatus only occupies a space of $23'' \times 10\frac{1}{4}'' \times 16''$, exclusive of the hopper and the engine, which, it is readily understood, is of very small dimensions, the hopper being made of any size required.

Fig. 1 is a front view of the apparatus attached to the front plate of the boiler, showing the double hinge by which the whole machine is swung clear of the firebox in the event of breakdown, and also the small engine which operates the whole mechanism.

The total weight of the stoker complete with engine is about 350 pounds.

Fig. 2 shows a side view of the friction gear for driving the crushing rollers and the gear for driving the same from the revolving "thrower" shaft. By altering the position of the adjustable quadrant the coal feed can be increased, decreased or stopped instantaneously.

Fig. 3 shows a perspective view of the handles which control the deflecting plates and also the small "sighting" doors, which can be opened to observe the operation of the crushers and the condition of the fire. These "sighting" doors fulfil the additional condition of admission of air on top of the firebox if the grate becomes "clinkered" before there is an opportunity of cleaning same, and by their operation the smokelessness of the furnace can be maintained at such a point that no smoke need issue from the smoke stack.

Fig. 4 shows the stoker declutched from the engine and swung clear of the firebox to allow of hand firing.

Fig. 5 shows how the deflecting plates are operated by their handles and held in place by the ratchets.

From this brief description it will be seen that the conditions, which are laid down in the previous article as essential in the mechanical handling of fuel for locomotives, and which are equally applicable to marine boilers, are all fulfilled in a satisfactory manner.

A point of greater importance in this matter is the reduction of labour effected by such a machine. It is here that a difference arises between the practice on land and on sea.

In the first place, it will be observed that it is an absolute necessity in the case of a locomotive that two men should be on the "footplate," and owing to the fact that it is impossible to provide any self-feeding or conveying gear for the coal from the engine tender to the stoker hopper, the fireman, who at present

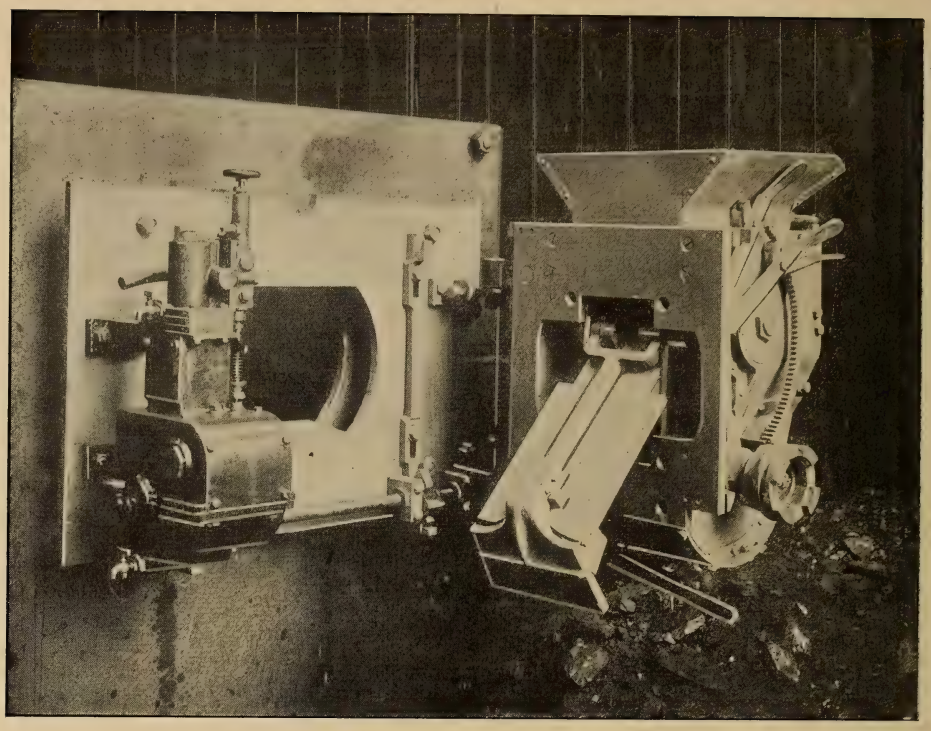


FIG. 5.—VIEW SHOWING DEFLECTING ARMS IN POSITION TO THROW COAL IN FRONT OF FIRE GRATE

shovels coal into the firebox, transfers his labour to shovelling the coal into the hopper. This fact disposes of the objections raised by "firemen's" unions that the use of mechanical stokers on locomotives is likely to cause any reduction of labour. These unions have, furthermore, argued that the very fact that a mechanical stoker is a "machine" necessitates a mechanic to attend to it. Such an argument is one which is easily upset by the facts of the case.

The work is not so arduous, nor does it involve the continual opening of the firebox door and facing of a red-hot fire, as the coal is just shovelled into the hopper, and the machine does the rest. Locomotive superintendents will appreciate the advantages of keeping the firebox free from inrushes of cold air and the consequent freedom from expansion and contraction of boiler plates. All the fireman has to attend to is the occasional movement of the "deflecting plates," in order to direct the coal to its proper position on the fire. The second point, as to skilled attendance, is a very small matter; the addition of a small, enclosed high-speed engine, such as is shown in the illustration, involves no more attendance than an occasional "oil up," in the same manner that the feed pumps or air brake pumps are attended to by the engine driver, and the fact that the fireman has more time to attend to this duty is an additional reason why there need be no difficulty in this respect.

Apart from this, the aims and object of every fireman is to become an engine driver, and his training throughout his career as a fireman tends to make him a "skilled mechanic."

The marine fireman works under different conditions, and it is here where mechanical stoking will most relieve the marine engineer.

There is no more unsatisfactory job on board ship than that of "hammering the firemen" to keep steam. If the bunkers are arranged (as may be easily done in most cases) to deliver the coal direct into the hopper, then a reduction of labour should be possible on the same lines as is now universally adopted on land. Even if the coal has to be shovelled into the hoppers, the effect on the "personnel" will be appreciated by those who have the control of the stokehold, as well as by the men themselves.

Two other points to which attention can be drawn are, the economy of fuel and the absolute smokelessness with which the coal is burnt under these conditions.

It is well known that mechanical firing is generally 10 to 15 per cent. more economical than hand firing, and especially will this be the case with locomotives where it is often necessary to use a high-class fuel for high-speed traffic. Where at present it is necessary to use a soft coal for prevention of smoke it will be found that the substitution of a hard bituminous steam coal, such as Northumberland or Yorkshire coal, will provide considerable economy, combined with smokelessness. An economy of 10 per cent. in the present annual use of nearly twelve million tons of coal as used in the United Kingdom will go a long way towards providing any capital expenditure involved in the fitting of such an apparatus.

The first indication of any steamer is generally the smoke seen on the horizon, and it is well known that "smoke" means incomplete combustion.

It is obvious that the shipowner will derive considerable benefit from the more complete combustion and consequent reduction of fuel by the installation of mechanical stokers, and the increased weight of from 3

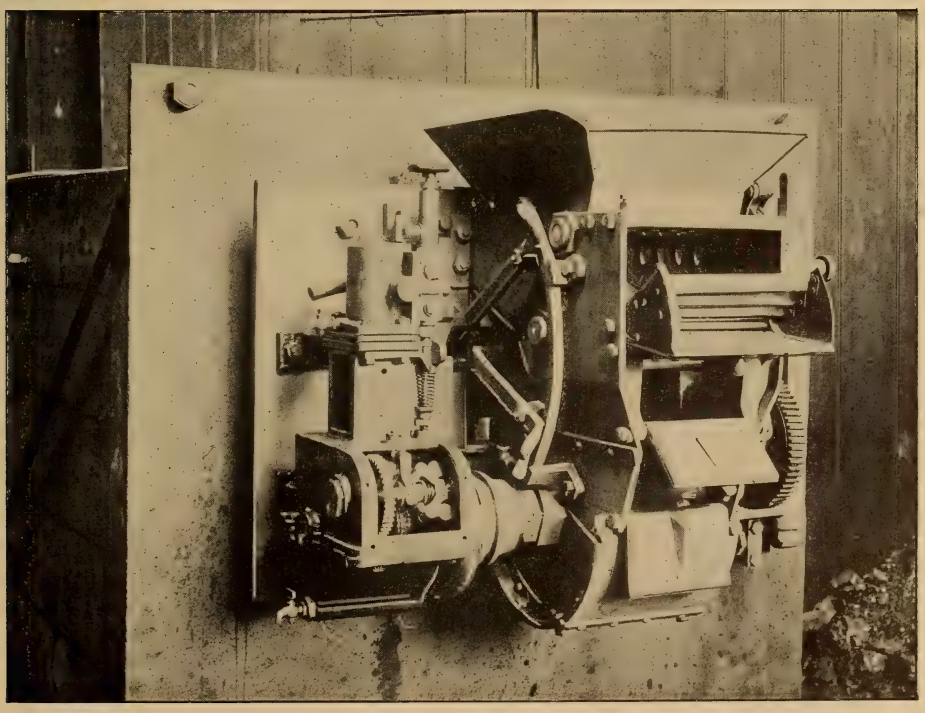


FIG. 6.—FRONT VIEW OF STOKER, SHOWING ENGINE

to $3\frac{1}{2}$ cwt. per firebox on any ship will be more than counterbalanced by the reduction of coal required for any specified voyage.

Then, again, it is of vital importance to naval manœuvres that war vessels should be able to approach as close as possible to the enemy without giving any indication of their appearance. To accomplish this feat it is necessary to use "Welsh steam coal," at a high price. By using a mechanical stoker, coal at a much lower price can be used, with equal effect as regards steaming capacity and smokelessness.

The by-laws of the local authorities against smoke in the United Kingdom are stringent to the last degree, and rightly so, and if a mechanical stoker will comply with the conditions imposed by the by-laws, it surely ought to be good enough for marine and naval purposes.

On the subject of repairs and maintenance, it is interesting to note that in the stoker under review the costs for repairs only amount to the cost of replacing the "cap" at the end of the top deflecting plate, a matter of, say, £1 per annum; there is nothing else to get out of order.

The subject of mechanical coal handling and the reduction of fuel losses in steam plants of every description is so important that any attempt to deal substantially with the problem should receive the earliest recognition, and it is with the object of drawing attention to what is believed to be the latest improvements that this article is written.

LARGE GAS AND STEAM ENGINES

By W. H. Booth

II.—LARGE STEAM ENGINES

In our last issue Mr. Booth discussed the development of the large gas engine, with numerous illustrations from recent British and Continental practice. The present article gives the corresponding development of the steam engine as at present constructed in large units, the illustrations being mainly drawn from British practice, but well representing the principles of best design in all parts of the world.—THE EDITOR.

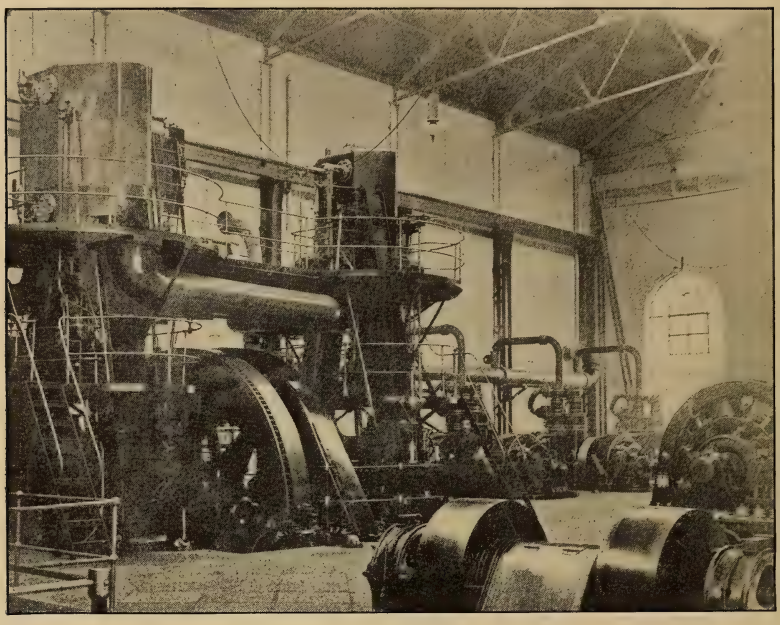
THE large steam engine has practically ousted the high-speed engine from a certain field of work since electric generators were made large enough for direct connection. Large units are seen to be right, as was plainly stated by Mr. Ferranti twenty years ago or nearly, but it has taken electrical engineers all this time to find out that Mr. Ferranti was right and that electrical power production must be carried on by means of large units of strength and solidity occupying a minimum of space in place of by rows of little high-speed engines. Rightly or wrongly, the large engine builders stood aside while the phase of high-speed hustle lasted, but lately have stepped forward again with engines not differing materially from the regular, comfortable, easy-going type of the factory engine, which, unless superseded by the steam turbine, bids fair to become standard practice for steam stations.

In recent electrical practice, generators having a capacity of 1,000 kilowatts and upwards are frequently specified, and Messrs. Yates & Thom have built many engines of this and larger sizes. Amongst them may be mentioned six vertical engines for the Manchester Corporation and four horizontal engines for the Lancashire & Yorkshire Railway Company's power station at Formby, each having a normal capacity of 1,500 KW. All these engines are of the cross-compound type, and have two cylinders with the generator between them. The Formby engines have cylinders 32-inch and 64-inch diameter, the stroke being 4 feet 6 inches, and they run at 75 revolutions per minute. The general design is clearly shown by the photograph, but special attention may be drawn to the massive proportions adopted to secure satisfactory running. The makers' special valve gear is fitted to these engines to secure a very wide range of cut-off to meet the extremely wide fluctuation of load, and the gear is drectly controlled by a very powerful high-speed governor. The total normal horse-power in the station is about 11,000 and the emergency load about 15,000 I. H. P.

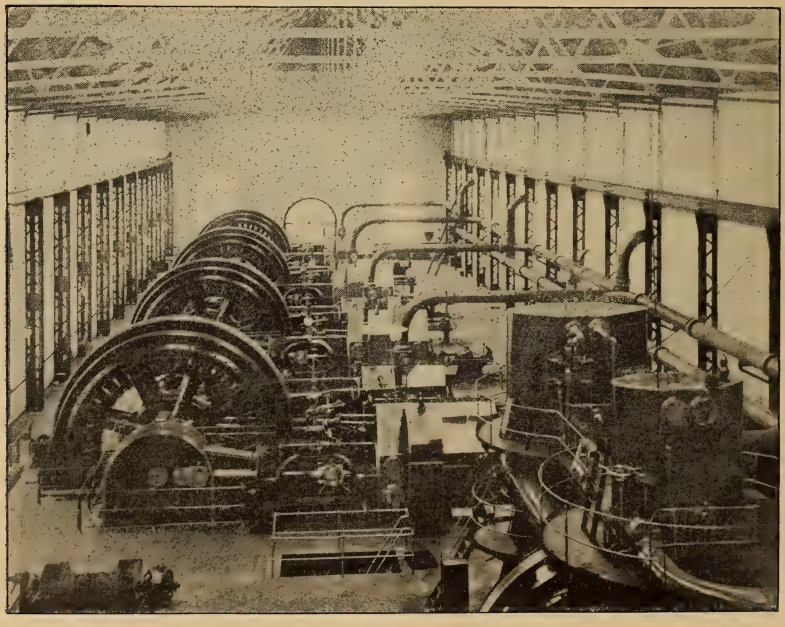
Similar engines have also been made for the Powell Duffryn Colliery Company, the Midland Electric Power Corporation, and others.

Four vertical engines have been supplied by this firm to the Leicester Corporation Tramways. One of these has cylinders 27 inches and 54 inches diameter and a stroke of 4 feet, and at 80 revolutions per minute develops 1,560 I. H. P. as its normal load; the three smaller engines have cylinders 23 inches and 46 inches diameter and 3-feet stroke, and give 780 I. H. P. at 95 revolutions per minute.

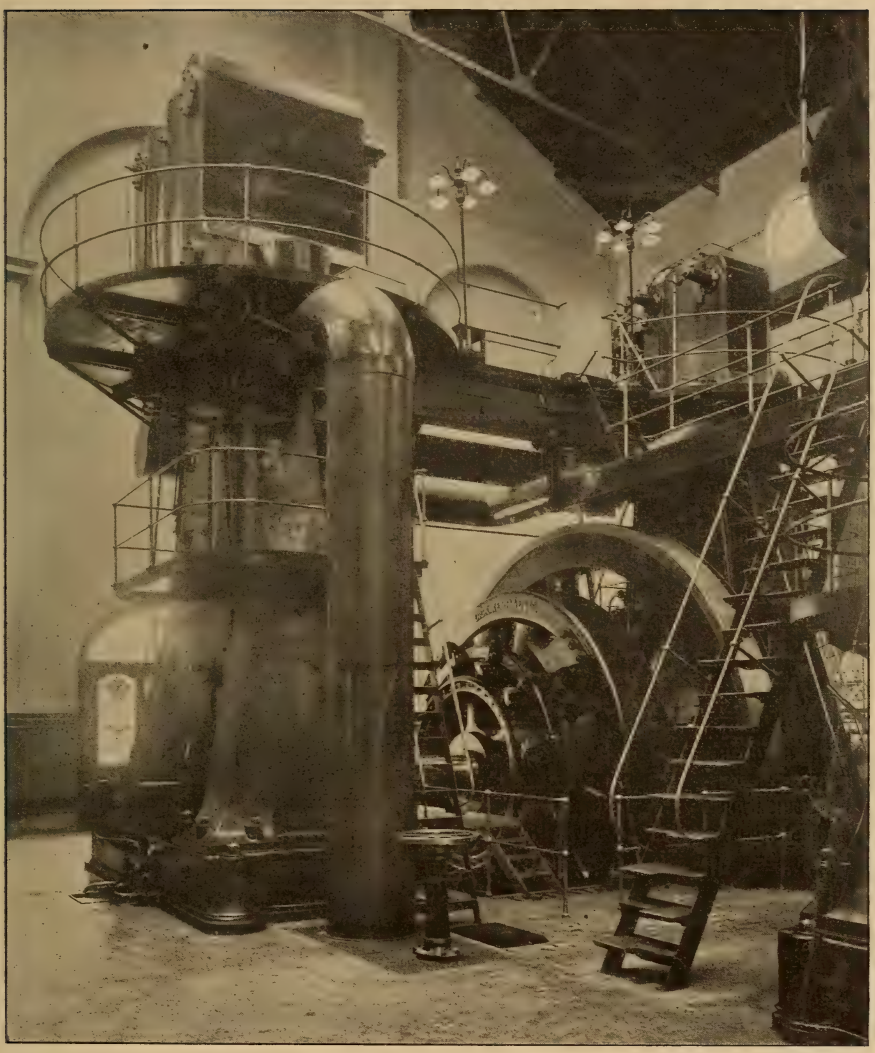
A firm which at one time probably did the bulk of its engine building for linen factories is now well recognized as engine builders for electrical work also. This is the old firm of Fairbairn Lawson, Combe Barbour Com-



LANCASHIRE & YORKSHIRE RAILWAY COMPANY, FORMBY STATION. VERTICAL ENGINE BY YATES & THOM, LTD., DEVELOPING 1 180 H.P.



LANCASHIRE & YORKSHIRE RAILWAY COMPANY, FORMBY POWER STATION. FOUR HORIZONTAL ENGINES, 2,400 H.P. EACH. YATES & THOM, LTD., BLACKBURN



STEAM ENGINES OF THE LEICESTER CORPORATION TRAMWAYS. YATES & THOM, LTD., BLACKBURN

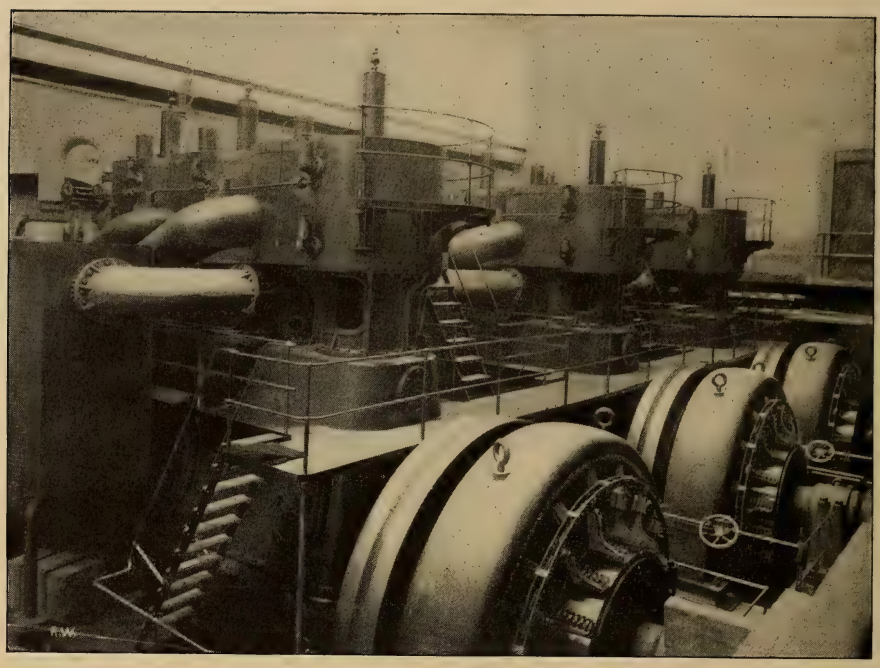
pany, of Belfast, who supplied the engines when the Belfast tramways were electrified.

The engine contract consisted of three engines of about 1,550 I. H. P. each, coupled direct to a 1,000 KW. compound-wound continuous-current generator.

The engines are of the inverted vertical triple expansion type, entirely enclosed, the cylinders being 22-inch, 33-inch and 50-inch diameter by 2-foot stroke. They run at 180 revolutions per minute and are supplied with steam at a pressure of 170 pounds per square inch superheated 160 degrees F.

The normal full load of each engine is about 1,550 I. H. P., but they are designed to carry an overload of 25 per cent. or 50 per cent. for short periods.

They have cylinders fitted with liners of specially hard cast iron, the space between the liners and barrels being utilized for warming up, and



STEAM ENGINES OF 1,000 K.W. FOR THE BELFAST TRAMWAYS

there is also a by-pass valve to each cylinder for warming and starting.

The pistons are fitted with Rowan's patent rings, the low pressure piston being of cast steel and the other of cast iron, all of them being the same weight for balancing facilities.

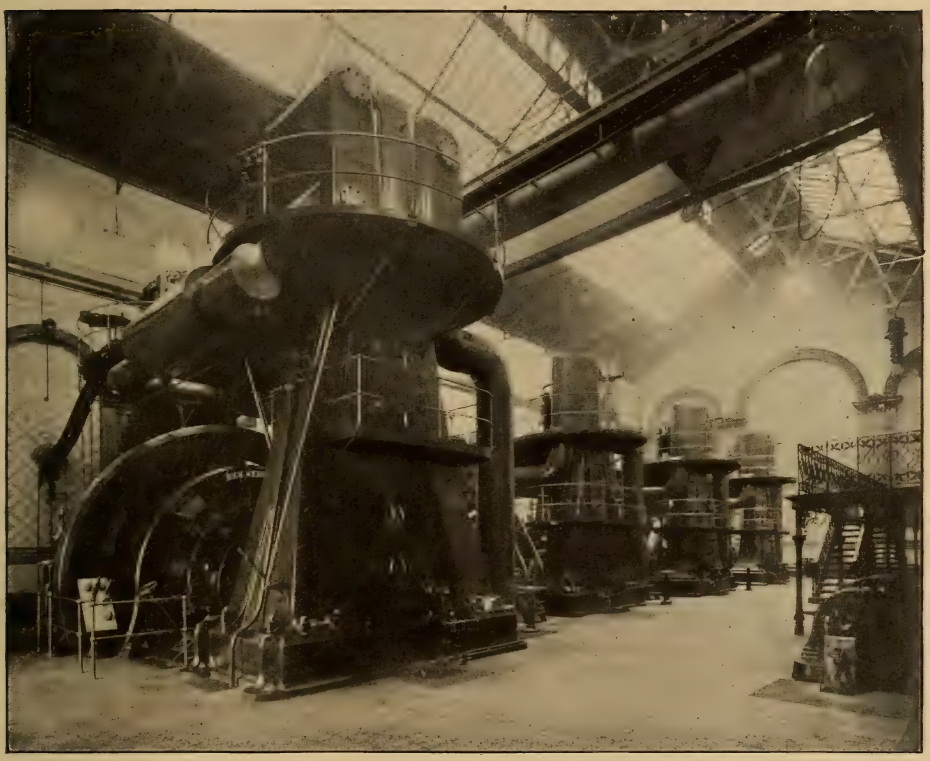
Oil is supplied under pressure of from 20 to 25 pounds per square inch from two valveless pumps placed inside the engine bed and driven by a separate eccentric, each pump being capable of supplying the entire engine with oil in case anything happens to cause the stoppage of the other. All the oil is passed through strainers in the pump suction pipes before being returned through the engines.

The main stop valves are of the "Globe" pattern, fitted with nickel steel seating for use with superheated steam, and there is also a small stop valve, leading to a by-pass throttle valve, which opens whenever the engine becomes overloaded and admits boiler steam to the intermediate cylinder, thus maintaining the speed.

The main throttle valve is bolted direct to the high-pressure cylinder casing and is of special design, no packing being required to keep the spindle steam tight; it is controlled by a powerful spring-loaded governor placed at the high-pressure end of the engine and driven by machine-cut gear wheels, the governor being adjusted to permit of a momentary variation of speed of not more than 6 per cent. when the full load is suddenly thrown off, and a permanent variation of not more than 2½ per cent. There is also a hand regulator to allow of the speed being varied 5 per cent. either way while the engine is running. All parts of the governor are supplied with oil under pressure.

The cylinder clearance volumes are comparatively small for this type of engine, and the piston valves and liners are so constructed that they may be drawn for examination by simply taking off the valve cover.

The method of fitting the valve liners allows them to expand indepen-



LEICESTER CORPORATION TRAMWAYS. ENGINES BY YATES & THOM, DYNAMOS BY DICK, KERR & CO.

dently of the cylinders so as to keep their shape under all degrees of temperature.

All the valves are partially steam balanced so as to reduce the frictional pressure on the eccentric sheaves

All the main bearings are fitted with magnolia anti-friction metal.

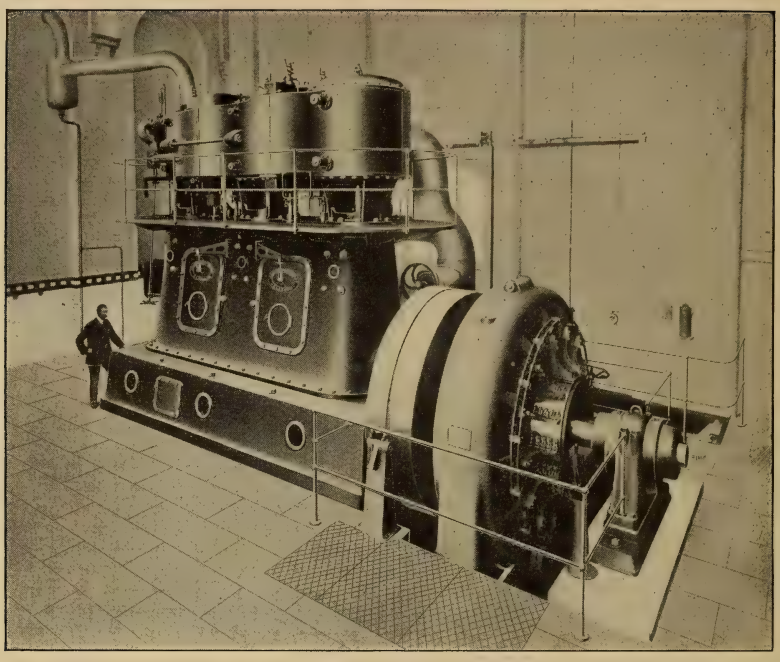
The faces of the fly-wheel form a coupling to which the generators are bolted, the energy of the fly-wheel and armatures being about 2,560 foot-tons. The fly-wheels are forced onto the end of the crankshaft with a pressure of 100 tons.

The crankshafts are made in one piece with cranks at angles of 120 degrees, and are bored up the centre and through the webs and pins for forced lubrication purposes.

Piston rods and valve spindles are fitted with United States metallic packing, and special provision is made that no oil from the crank chamber passes up into the stuffing boxes, the cylinder distance pieces being fitted with drains to carry off drips from the glands, etc.

One of the features of the engines is the accessibility to all the working parts for examination and repair. Large doors have been left in the crank-chamber sides and, through these, not only can the connecting rods, eccentric, etc., be taken out, but also the cross-head slides. The crank-chamber glands can also be removed without breaking a single joint of the cylinders or valve chests, as is so often necessary with other types of enclosed engines.

By simply screwing out plugs in the cylinder covers and without removing the covers, the pistons and rods can be drawn up and held in their highest position by the engine house crane. Long eyebolts are screwed into the ends of the piston



HIGH-SPEED ENGINE, 1,000 HORSE-POWER. JAMES HOWDEN & CO., GLASGOW

tail rods, the end of these bolts being caught by the crane hook.

The engines are arranged to run either condensing or non-condensing, and a large "Worthington" oil separator is placed in the exhaust pipe to extract all grease from the exhaust steam before entering the condenser and returning to the boilers.

The above description is characteristic of much of the best slow steam engine practice of the present day.

The idea of some people that in electrical work there are special stresses to be considered is somewhat erroneous. These special stresses do not exist in a properly designed engine. Sudden variations of load, of course, place a stress of great amount in the shaft between the fly-wheel and the armature, but there can never be a greater stress in, say the piston rod, than that due to the steam pressure, and a steam engine, if designed at all, is designed for maximum steam pressure. The once common practice of placing the armature and fly-wheel at opposite ends of the crankshaft was a foolish and illogical one, for it placed on the crank pin the whole of the stresses due to fly-wheel effect. All good modern designs aim to make a direct connection between the dynamo and the fly-wheel so that no stress variations from the fly-wheel pass to the dynamo by way of the shaft. The shaft merely transmits to the fly-wheel the steam energy from the cylinder, and the maximum stress in the shaft is that due to the maximum steam pressure that came upon the crank pin at the moment when the leverage of the virtual crank multiplied by the pressure on the piston is a maximum. This stress provided for, there can be no greater stress due to sudden variations of load so long as the fly-wheel is directly attached to the generator. It is quite different when the fly-wheel and generator are at opposite ends of the crankshaft, yet this method of construction was that followed by those who made most capital out of the variable stresses bogy which they

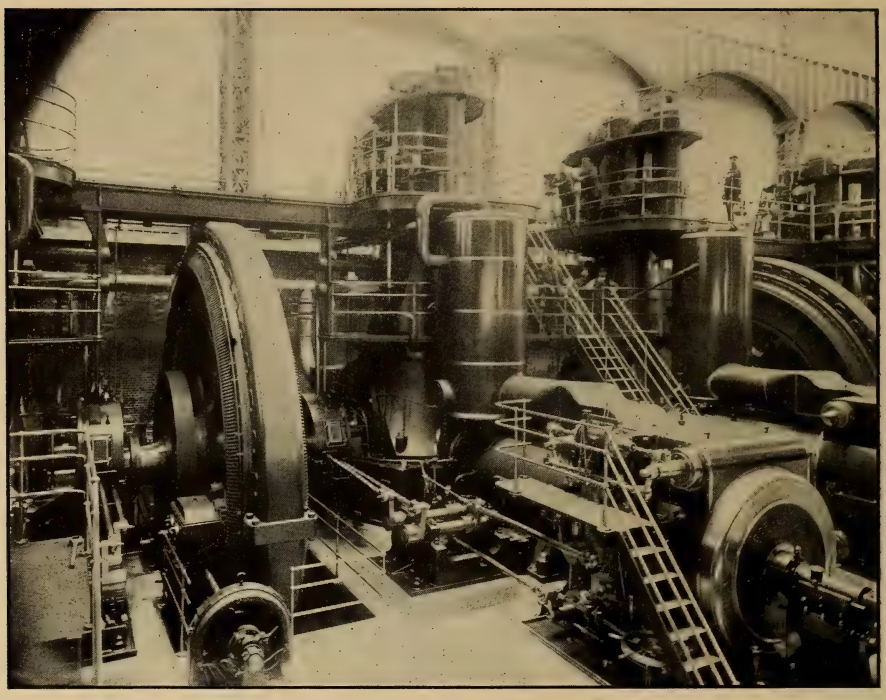
denied in their own actual practice.

Even the so-called high-speed engine has grown to large sizes, as shown opposite, which represents the 1,000-KW. set by James Howden & Co., of Glasgow. The modern high-speed engine has practically developed into a simple variety and the most successful are those which have adopted this crystallized form, so that there is really very little difference in the appearance of the most successful of the high-speed engines.

They have cylinders, an open space between the cylinder gland and the top of the enclosed casing. They have cross-heads, guides, connecting rods of normal form and a crank-shaft, and generally resemble little marine engines put inside a closed box and fitted with forced lubrication.

In large steam engines, no firm has of late done more prominent work than Musgrave & Sons, of Bolton. The large engines at the station of the Glasgow Tramways are of their make, and in the illustration is shown a part of the London County Council power station at Greenwich, which is peculiar to England in that the high and low-pressure engines on either side of each pair take hold of the same crank pin, the low-pressure cylinders being horizontal for convenience of drainage, the steam being but slightly if at all superheated. Indeed, for superheated steam, Messrs. Musgrave prefer not to employ the Corliss valve, and in the illustration is shown a four-cylinder triple-expansion engine of 2,500 I. H. P. with rope driving for factory work, and the Stegen's patent drop valve for superheated steam, for which Messrs. Musgrave are licensees in Great Britain and in the Colonies. The drop valve in its various forms appears at present to be the most suitable valve for use with superheated steam, and would of course be employed in a modern steam power station of high

ENGINES AT THE LONDON COUNTY COUNCIL TRAMWAY STATION, GREENWICH. MUSGRAVE & SONS, LTD., BOLTON



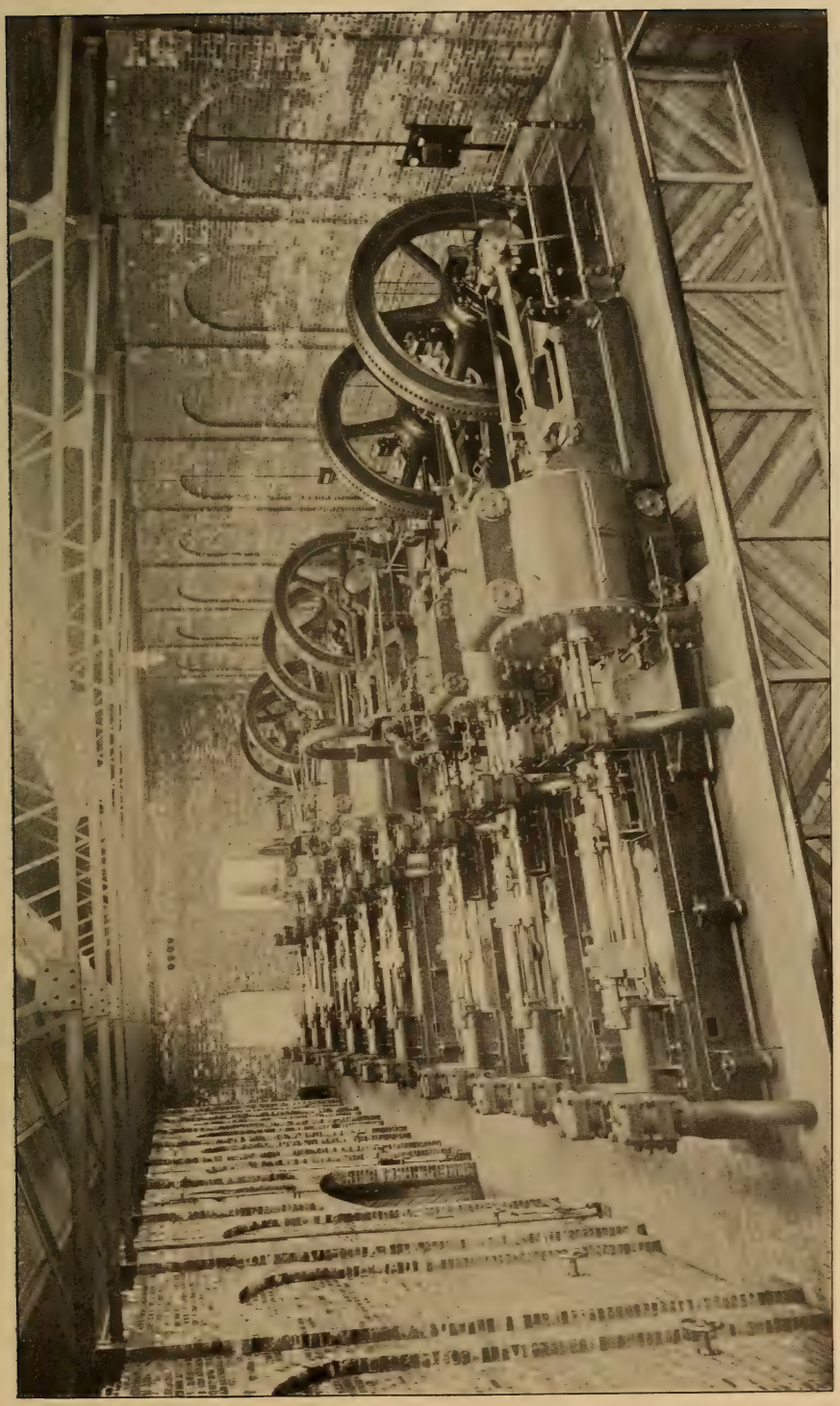
ANOTHER VIEW OF ENGINES AND DYNAMOS AT THE GREENWICH TRAMWAY STATION

order. There are also shown three horizontal pumping engines by the same makers, each of 500 I. H. P., the smallness of the water ends affording evidence of the intensity of the hydraulic pressure which these engines generate.

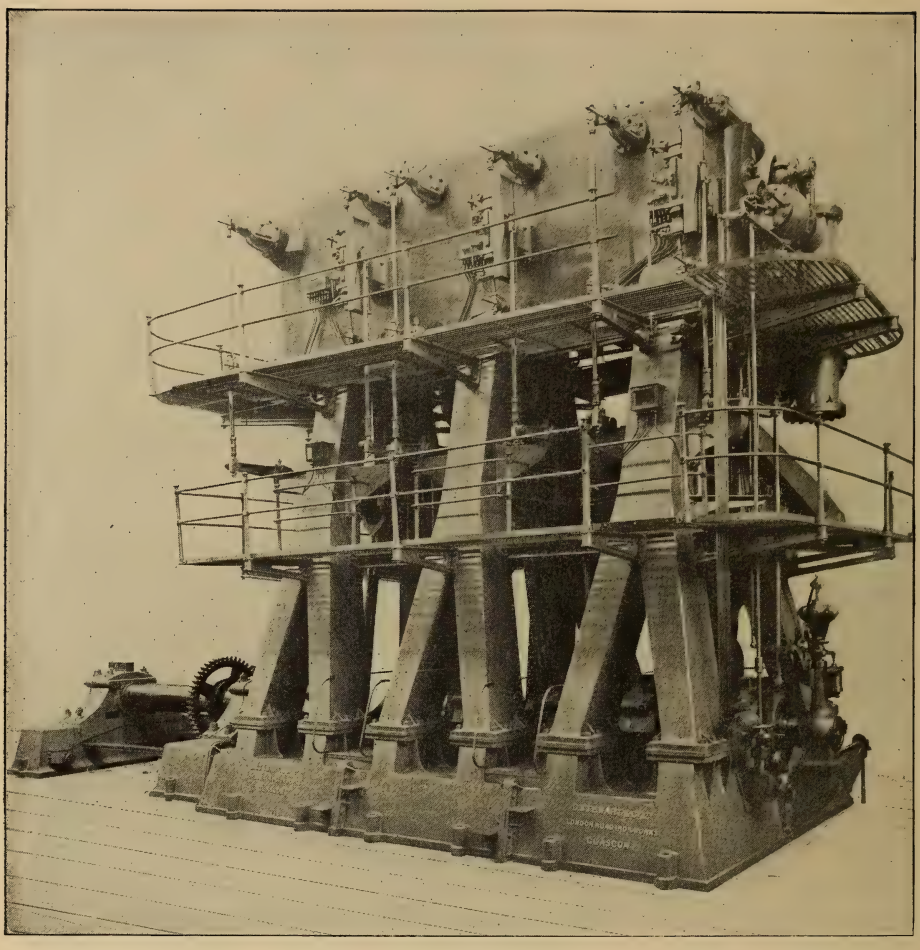
Among the large engines are shown the class of engine of about 2,000 horse-power, such as Messrs. D. Stewart & Co. have developed for the driving of Indian and other cotton mills. These are of the inverted vertical type of treble expansion engines with cylinders 24-inch, 38-inch and 63 inches diameter and a stroke of 54 inches.

The same firm's 810 horse-power engines as supplied for driving electric generators in Western Australia is also illustrated. This engine is practically a replica of those in the Glasgow Tramway power house, and has cylinders 22 inches and 40 inches by 42 inches stroke, and develops the above power when run at 90 revolutions per minute. The fly-wheel and the electric generator are placed between the two cylinders and the valve gear is of Reynolds Corliss type as well in the above engines as in others made for Dublin, two of which have cylinders 28 inches and 58 inches diameter and 48 inches stroke, and develops 1,620 horse-power driving direct on three-phase alternators at 84 revolutions per minute.

Three pumping engines have been made for the Patrick pumping station of the Glasgow Corporation main drainage scheme to the designs of Mr. D. Home Morton, each to give 160 indicated horse-power at 21 revolutions per minute and 155 pounds pressure per square inch at the stop valve. They are of the inverted vertical cylinder triple expansion surface condensing type, with steam jackets on the barrels of all three cylinders. The ends or heads of the cylinders containing Corliss valves are cast separately from the cylinder bodies, to which they are secured by studs. Between each pair



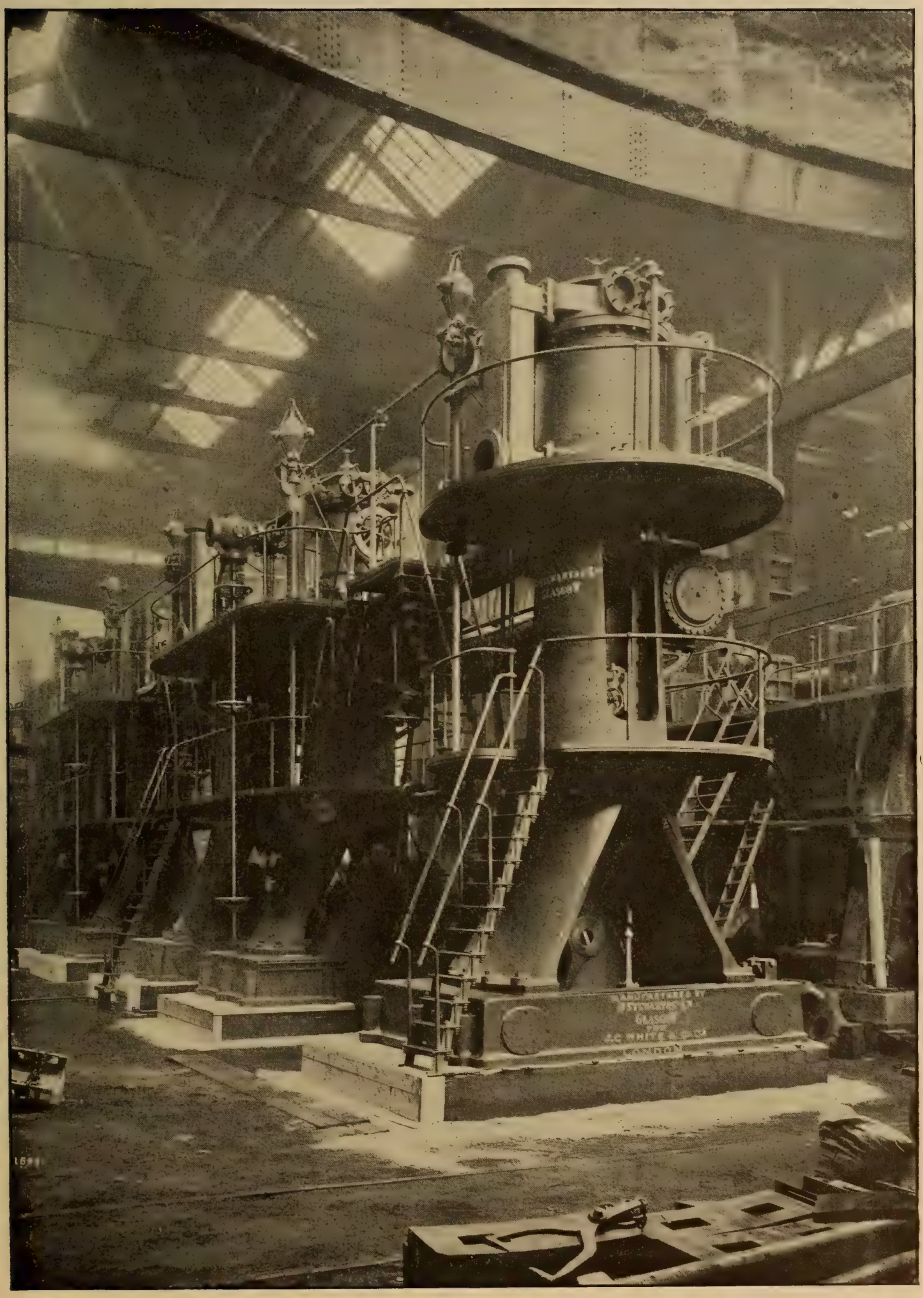
THREE HORIZONTAL HYDRAULIC PUMPING ENGINES, EACH 500 INDICATED HORSE-POWER. MUSGRAVE & SONS, LTD. BOLTON



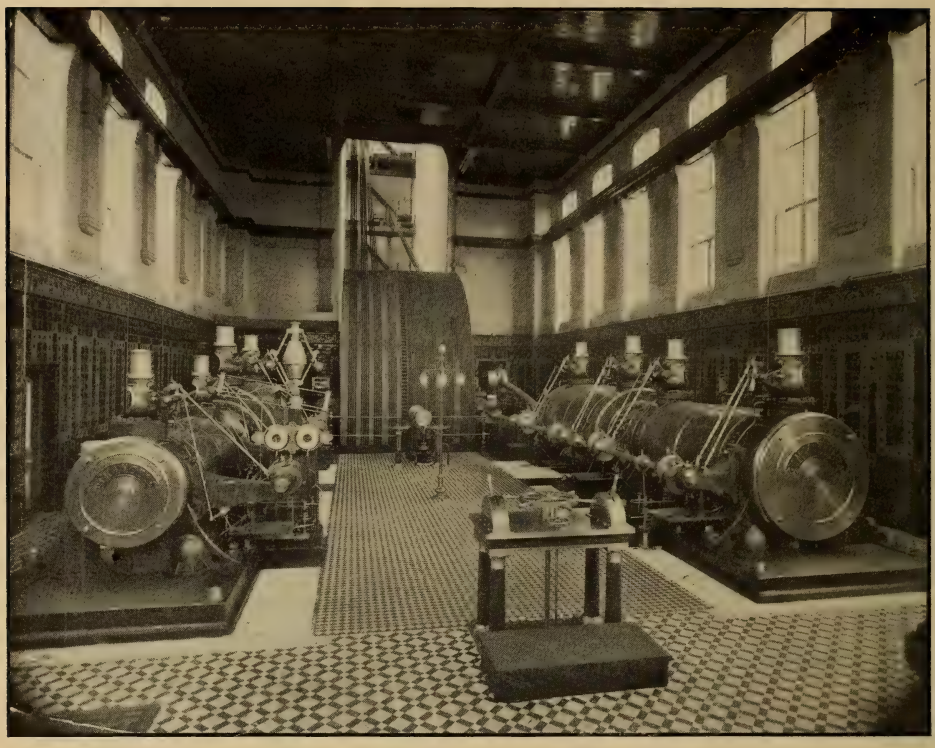
TRIPLE-EXPANSION FACTORY ENGINE, 2,000 HORSE-POWER. D. STEWART & CO., GLASGOW

of cylinders are receivers containing tubes from which the steam passes on its way from one cylinder to the other. The outside of these tubes is surrounded by live steam, the receivers being thus jacketed or "reheater receivers." The valve gear is of the direct connected, eccentric type with Messrs. Stewart's modification of the Dobson trip gear on the admission valves. The cut-off under ordinary circumstances is automatically varied by the governor but can if necessary be varied by hand on each cylinder. The governor is of the high-speed Porter type, driven by Hans Renold chain from the crankshaft. Gear is attached to the governor much in the same way as the back gear to a lathe, so that the governor can act when the engine is running at three different speeds, depending on the amount of water to be pumped. The surface condenser is situated in the main outfall pipe, so that all the sewage pumped passes through the tubes, which are of specially large diameter, the steam being condensed on the outside of the tubes. The air pump and hot well pump are worked from the pump cross-head on the single low-pressure side of the engine.

The pumps are of the displacement type with gun-metal plungers. The pump casings are of cast iron, the valves of the hinged type are also



CROSS-COMPOUND VERTICAL ENGINES FOR POWER STATION IN WESTERN AUSTRALIA
D. STEWART & CO. GLASGOW



FOUR-CYLINDER TRIPLE-EXPANSION ENGINE, 2,500 HORSE-POWER. FITTED WITH STEGEN'S PISTON DROP VALVES. MUSGRAVE & SONS, LTD., BOLTON

of cast iron lined with leather, and the frames on which they work are of gun metal. Air vessels are placed on the suction side of the pump and on delivery below the high-pressure and low-pressure sides of the engine.

The diameter of the high-pressure cylinder is 15 inches, of the intermediate cylinder 24 inches, and of the low-pressure cylinder 40 inches. The stroke of all three cylinders is 4 feet 6 inches. The diameter of the three main pumps is each 38 inches and the stroke 4 feet 6 inches.

A test of one of the above pumping engines was made, from which it appeared that the pumps running at 22 revolutions per minute delivered 12,800 gallons, and at 20 revolutions 11,550 gallons per minute, or somewhat more than was specified. The steam consumption was 11.43 pounds per indicated horse-power-hour, or considerably below the amount guaranteed; the ratio of water horse-power to indicated horse-power was, on the average, 85 per cent. This is a very high figure, rather higher perhaps than what one is justified in expecting, and was much above that specified and guaranteed.

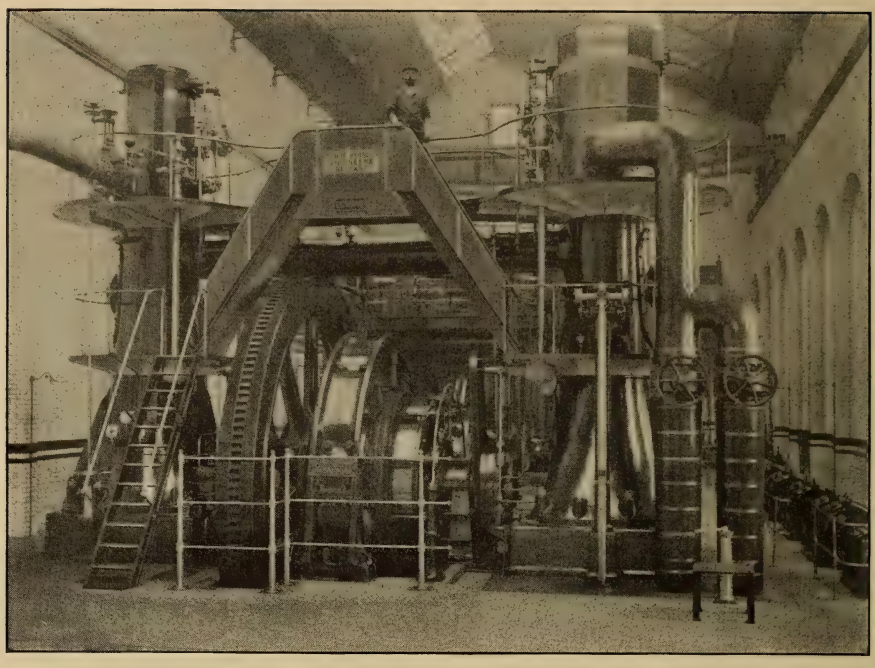
One of the great desiderata of the large steam or gas engine is regularity of turning, especially when driving alternating-current electric generators in parallel with each other. In the course of one revolution there must not be a serious angular displacement. This can be reduced to anything desired by the use of a fly-wheel of sufficient weight, but a very heavy fly-wheel possesses also the disadvantage that the synchronizing effort of the generators cannot exercise itself, and sometimes heavy fly-wheels are apt to set up an angular oscillation. Then it is essential that the governor shall be sensitive in or-

der that it shall respond as soon as possible to the changes of load as they occur. Strictly speaking, it is the fly-wheel which is really the governor of an engine. The governor so called merely regulates steam admission, after the event of more or less load has occurred, and while the inertia of the fly-wheel is acting to prevent too rapid change of speed due to change of load. In the best engines, governing is effected in such

PUMPING ENGINES FOR GLASGOW MAIN DRAINAGE. PATRICK PUMPING STATION. D. STEWART & CO., GLASGOW

a way that the engine does not run very much faster when lightly loaded than when fully loaded. Should the governor try to overdo its duty, it will reduce speed at no load below that at high load and will cause hunting. In a well-balanced compromise the engine carries a sufficient weight in its fly-wheel and a promptly acting governor that does not overrun. In governing, one can never so arrange matters that an engine at no load shall not be full of what may be termed a full load of steam, the work in which cannot be reduced until the steam has run through the engine. While this steam is going through the engine it is adding speed, and the inertia of the fly-wheel is the only thing that can serve to prevent too great a speed variation pending the getting away of this steam, and, similarly, the engine now run empty of its working fluid, may suddenly be asked to turn its full load and must again be helped by the fly-wheel inertia to keep matters steady until the action of the governor and a sufficient lapse of time have enabled the engine again to become charged.

A continuously steam-fed turbine should be less exposed to such varying influences, because the steam gets into and out of the turbine so very rapidly, but cyclic irregularity is introduced when regulation is by the method of gusts, which is therefore so far an added disadvantage to the



BELFAST TRAMWAYS. THREE 1,500 HORSE POWER ENGINES FAIRBAIRN-LAWSON-COMBE-BARBOUR COMPANY

temperature variations which this method also introduces. That there will be keen competition in the near future between the steam turbine and the reciprocating steam engine is probable enough, but the prospects of the engine have not been made worse by sundry careless treatment of the interests of the turbine as well as by certain neglect of the prejudices of the mechanical engineer in regard to constructional details.

But, as already stated, the reciprocating principle will for a long time find support from the side of the gas engine. There is no successful gas turbine yet to be had, but there are patents to be purchased for a paltry few thousand pounds, none of which, that the author has yet seen, being of any serious value, and indeed no serious prospect is in view that the gas turbine is likely to be a success, so grave are the present difficulties in respect of materials and temperatures.

With these possibilities of the near future we may therefore look forward for considerable life to the reciprocating engine, especially when it is a gas engine. Meantime, without fighting for the gas turbine, constructors have plenty of time to be busy over the materials of construction that will work with the highest possible temperature of superheated steam, or that will permit of a gas engine being worked at a higher than present temperatures. Yet in all the electric power stations of England and America there are not yet three that possess even controlled temperatures of superheat of steam, though this question must be faced by those who do not wish to see their station costs made to look foolish by some gas driven station.

It is indeed a strange commentary on the average practice of the engineer that, while many are pushing hard for the realization of the economy that is to be had from the employment of gas engines, the users of steam cannot be made to see the importance of a rational system of super-

heat. Thus in that most modern of steam engines, the turbine, the blades are still usually made from some copper alloy which will not bear superheated temperatures satisfactorily. With others, superheat is treated as of quite insignificant importance; the value of a steady temperature is unrecognized and great risks are incurred by using in unsuitable engines steam that is usually too little superheated, and may any day wreck things by being too highly superheated. Multiplicity of boilers and of superheaters is a more or less valuable safeguard against the excessive temperatures furnished by some of a group. Danger, of course, comes in when the casual coincidence takes place, and casual coincidences can be mathematically shown to be certain in a given time, and may occur now or at any period in that given time. Engineers who have had the opportunity of running the same plant with and without superheat can speak of the great reduction of fuel which superheat brings about. But correct practice will see to it that the steam temperature is kept steadily at one constant figure, and will attach even more importance to this than to the maintenance of steady pressure. Only by superheat can the best results be obtained from the steam engine, and every day places the gas engine in a better position to obtain a recognition for its undoubtedly superior thermal advantages. For in the gas engine the gases are already highly superheated and are indeed often discharged at a temperature higher than the initial temperature of superheated steam.

Better to utilize the heat of the working fluid in the gas engine, it only remains to discover some material of construction that will not demand such efficiency of cooling as now furnished by the jackets of the gas engine, for it is to such cooling that the gas engine is prevented from doing twice the duty per pound of fuel which it now accomplishes.

Advantages and disadvantages are therefore well sprinkled between steam and gas power, but for land purposes no one can study the course of events without arriving at the conclusion that the future holds out more hope for gas than for steam.

This article could scarcely be closed without making a comparison between electrical and marine practice in steam engines. For years the makers and users of engines for driving electric generators discussed the steam engine as though no big engines had ever been made except for electrical work. It has been a continual marvel to steam engineers that the builders of large marine engines did not enter the field of electrical work. Thirty years ago marine engines were little smaller than the biggest engines used to-day on land. Much trouble and cost would have been spared had marine experience been drawn upon as an aid or guide in large power-station design, for there can be no doubt that both in reciprocating engines and in turbines marine designers stand an easy first. They are no doubt already keeping an eye upon the possibilities of the internal-combustion engine for marine purposes, and though 4,000 horse-power is about the maximum size gas-engine unit at present available, it would hardly surprise the engineering world to find some great naval works taking as long a forward step with the gas or oil engine as was taken with the steam turbine when the new Cunard steamships were completed.

THE AMERICAN FLEET FROM AN ENGLISH POINT OF VIEW

By Archibald S. Hurd

In our issue of October last there was published the first portion of this analytical examination of the strength and weakness of the navy of the United States, and it was there shown that while the American navy was entitled to rank second in strength among the great powers, so far as ships are concerned, it still lacks in numbers of officers and men, according to European standards. The present strength of the fleet was carefully reviewed, and a judicial opinion given concerning the position of the United States upon the water. In the present, and concluding paper, Mr. Hurd reviews the latest additions to the fleet, as well as the programme for naval construction now in execution, the whole enabling a broad and disinterested view of American naval strength to be obtained.—The Editor.

THE United States Navy has not only attained the position of the second sea power of the world, as judged by statistical methods, but it has reached a high standard of efficiency, as is shown by the gunnery records. It is one thing for a nation to possess a number of ships of various classes which look impressive when set out in an official statement of strength, and it is quite another for it to spend large sums on pay for officers and men, coal and stores of all kinds to enable those ships to keep the seas and thus enable the personnel to become proficient by continual drill in the essential war duties. It is one of the virtues of the American authorities that they have always recognized the supreme importance of expenditure upon the fleets at sea which are the training centres for war. Consequently the ships of the United States Navy represent actual fighting power and are not inert masses of material, which can be translated into terms of war only after months of delay—even provided the enemy gives sufficient opportunity to put a war edge on the tools which have been provided at so much cost. The ships of the United States stand for real sea power, a form of sea power which is characteristic of the republic, energetic, thoroughly alive and resourceful. It has not the same rule of thumb disciplinary veneer as is to be found for instance in the German Navy, but about the whole fighting machine there is an assurance that on the day of battle it will give a good account of itself. The ships, in fact, are ships of war, and in examining the standing of the navy in vessels of various types, no reservations have to be made as in the case of some European fleets whose men-of-war appear more formidable on paper than they will, or can, ever show themselves to be in war.

BATTLESHIPS.

Of the twenty-one first-class battleships which are now either completed or being built for the American fleet practically none which is now likely to be regarded as fit for the first line was launched before 1901. In that year, after an interval of three years, during which no battleship of the United States took the water, three vessels of medium size, the *Ohio, Maine* and *Missouri,* of 12,300 tons displacement, were launched. For a nation geographically situated as are the United States, these vessels were unsatisfactory because their coal capacity at normal draft is limited and the freeboard is low, giving the three ships an inadequate command of fire. In these three ships not only was fire-

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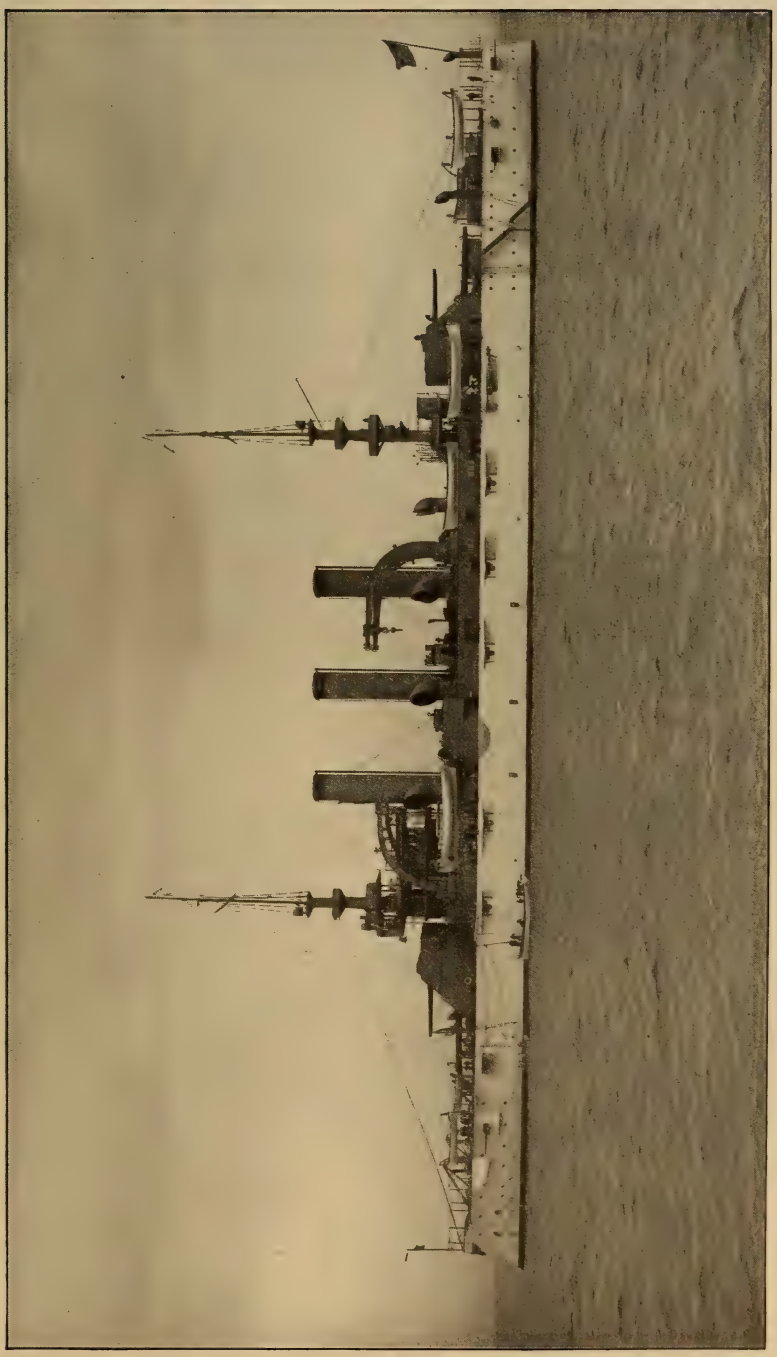
THE BATTLESHIP MAINE. IN THIS CLASS ALSO ARE THE MISSOURI AND THE OHIO.

proof wood introduced, but a corn-pith, or cellulose, backing to the belt along the waterline was used at a time when it was thought this departure would tend to neutralize the effect of explosions; British experiments, however, have tended to discredit this idea. A much finer type of ship followed when the American Navy Department laid down the five vessels of the *New Jersey* type, with a displacement of nearly 15,000 tons, complete armoured belts with a maximum thickness of 11 inches of Krupp steel, and an armament of four 12-in. 40 calibre guns, eight 8-in. 45 calibre guns, and twelve 6-in. 50 calibre guns. In these five ships the American naval authorities introduced the superposed turret as carried in the *Kearsarge* and *Kentucky* built some years previously and now, in spite of extensive repairs, very much in background. With the application of the superposed turret to the *New Jersey* design the controversy with reference to this innovation broke out once more with increased violence. For some time the discussion proceeded in all parts of the world and it is not possible to say what the general verdict was. It is certain that in later European ships this plan has not been adopted and that other navies have fought shy of an experiment which conservative designers from the first view with considerable suspicion. The superposed turret, however, conferred apparent considerable advantages, and above all else enabled a concentration of guns to be mounted in these medium-sized battleships which under other circumstances would have been impossible. While contemporary British ships were obtaining only 12-inch and 12 to 14.6-inch guns, the American constructors were enabled to mount in each of the *New Jersey* type ships eight 8-inch guns beside the main armament of four 12-inch weapons and twelve 6-inch quick firers. Admitting the principle of superposed turrets, these battleships were the most powerful then under construction. Four of the 8-inch guns were placed in the two superposed turrets fore and aft and the other four 8-inch weapons were mounted on either beam forward, thus giving a broadside fire of four 12-inch guns, six 8-inch and six 6-inch, the last named weapons being placed on the main deck. The *New Jersey vessels* were equipped with

Babcock & Wilcox boilers, except in the case of the *Georgia,* which was given generators of the Niclausse type. These five ships formed a useful type which on trial exceeded 19 knots. In the design next undertaken a further increase in displacement was made and devoted to armament and armour. The two battleships *Connecticut* and *Louisiana,* which were authorized in 1902, correspond in the general lines of their design with the British battleships of the *King Edward* type, though in displacement they are a trifle smaller. It was decided in these ships to abandon the superposed turret and to mount the 8-inch weapons in pairs at the corners of the superstructure, with twelve 7-inch quick-firers in the central battery on the main deck. These two ships are not only heavily armed, but are very strongly protected. The vitals are defended by an 11-inch belt, and the protected deck is 2½ inches thick on the slope and 1½ inches on the flat. They are as fine ships of their date for offense and defense as are to be found in any navy in the world, but in making provision for only 4,000 tons of armour and armament, and ammunition weighing 1,536 tons, some economy was practiced in the engine room. These vessels have a speed of only 18 knots, a decrease of a knot in comparison with the preceding class, although on trial both of them obtained a mean of 18.8 knots. Once more the orders for boilers went to Babcock & Wilcox, whose design has been almost consistently selected by the American Navy Department. Following these two ships, Congress harked back in the following year to battleships of moderate dimensions, and orders were given for two ships —the *Idaho* and *Mississippi,* with a displacement of 13,000 tons, considerably less speed, and lighter armour, the main belt, instead of being 11 inches as in the *Connecticut,* being reduced to a maximum of 9. In spite of the reduction in displacement it was found possible to mount in these two vessels the same number of heavy guns, but instead of twelve 7-inch pieces, each was given only eight, and some reduction was made in the number of anti-torpedo quick-firers. At the same time, however, Congress, while authorizing the construction of these two ships of small dimensions, gave orders for four more vessels of the *Connecticut* class to be put in hand. In the design of these later ships some slight improvements were made, but the main belt was kept of the maximum thickness of 9 inches, but this weight was applied at least in part to give the 12-inch guns a protection of 12 inches in place of 10 inches in the *Connecticut* class of vessels. Subsequently, two more vessels of improved *Connecticut* type—the *Michigan* and *South Carolina,* also 16,000 tons displacement, were approved by Congress and these vessels have lately been laid down. They represent the one big-gun type carrying eight 12-inch weapons and are indeed small *Dreadnoughts.* In two or three years' time consequently the head and front of the American fleet will consist of eight of the finest battleships to be found in any fleet, each displacing 16,000 tons, six provided with an armanent of four 12-inch, eight 8-inch and twelve 7-inch quick-firers, and two carrying each eight 12-inch guns besides the anti-torpedo armanent; and behind this magnificent group, which has no counterpart in any other country except the vessels of *King Edward VII* type, will be the *Idaho* and *Mississippi,* the vessels of the *New Jersey* type and the three ships of the *Maine* class, with nine older battleships in the background, which by 1910 will probably have been relegated permanently to the reserve, together with a number of coast defense ironclads whose usefulness has to a large extent departed in view of the great increase of defensive and offensive power of European battleships. By 1911 the American fleet will be further strengthened by the completion of the two battleships of the *Dreadnought*



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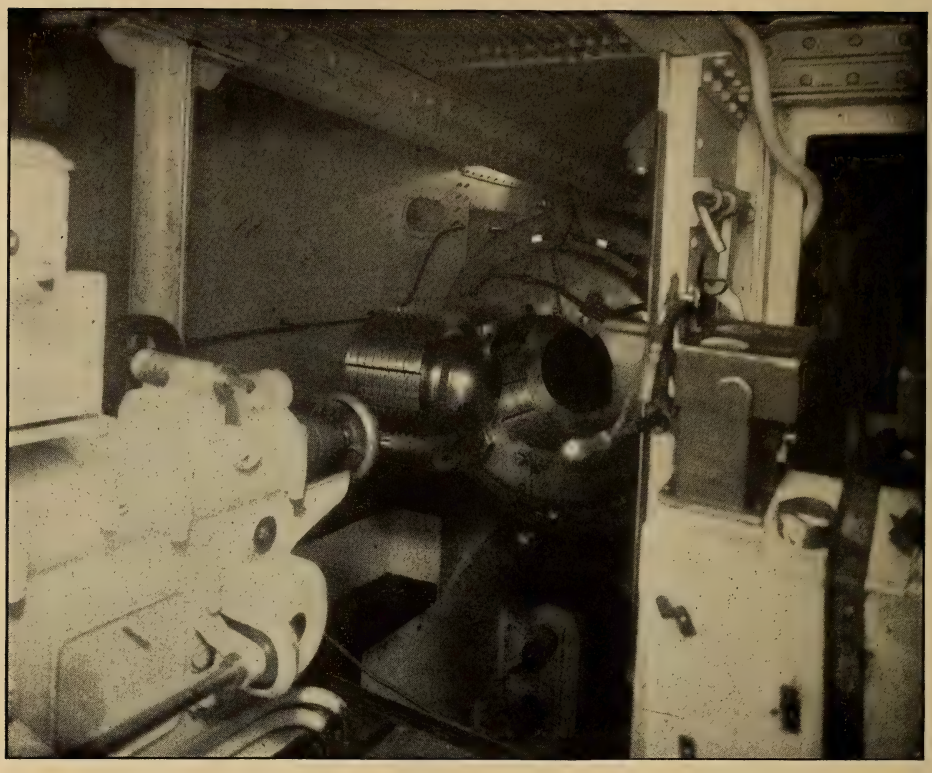
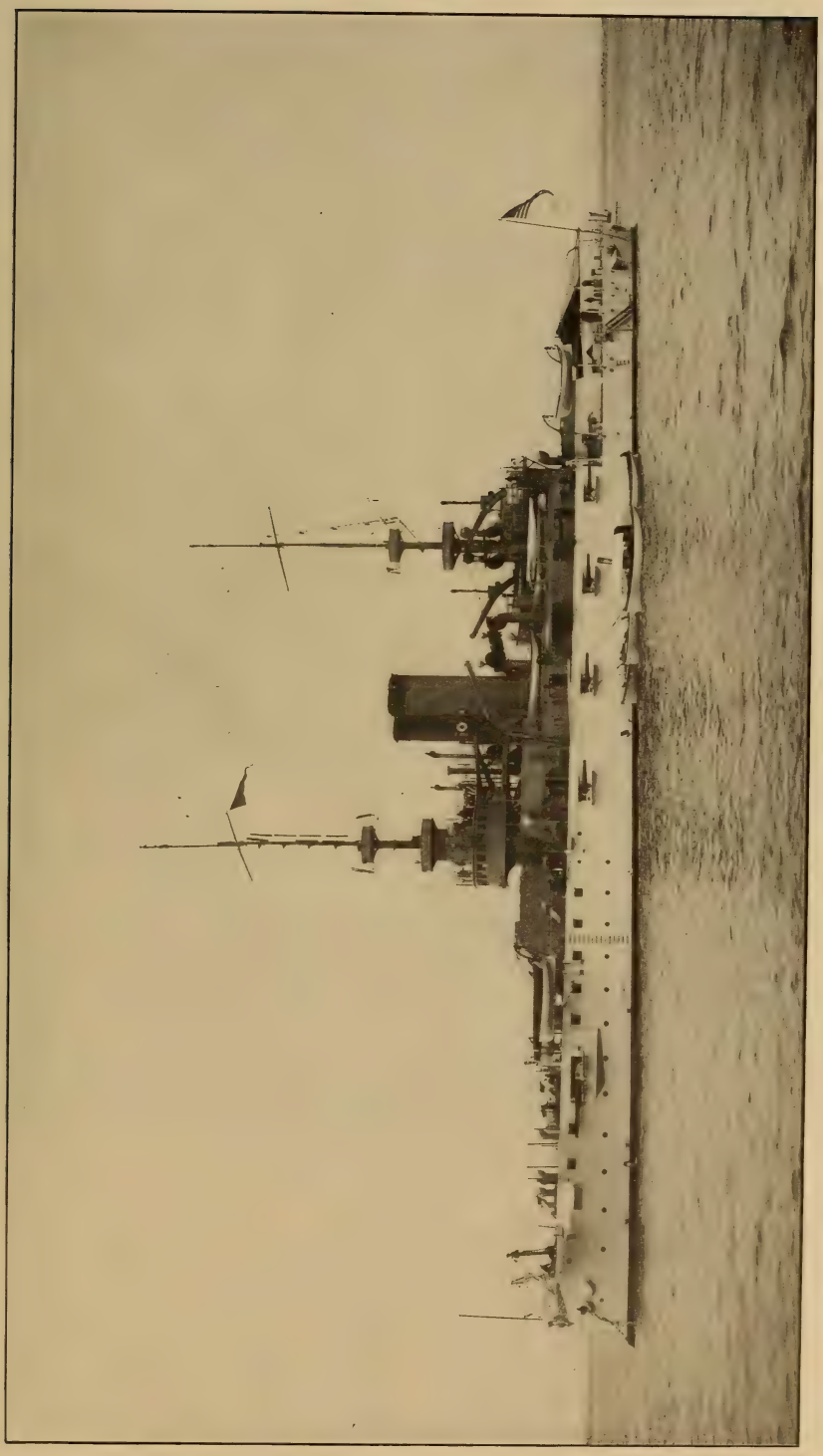
BATTLESHIP NEW JERSEY, SHOWING SUPERPOSED TURRETS THIS CLASS INCLUDES THE RHODE ISLAND, VERMONT AND VIRGINIA



INTERIOR OF TURRET ON BATTLESHIP CONNECTICUT, SHOWING OPEN BREECH OF 12-INCH GUN, AND UPPER PORTION OF AMMUNITION HOIST.

class which have recently been ordered. These ships are very remarkable, because, while Germany is credited with battleships of 18,000 tons, which, it is reported, will carry no fewer than sixteen weapons of 11 inches, the American designers are satisfied that not more than ten 12-inch pieces can be advantageously mounted even on a displacement of 16,000 tons. Greediness for gun power is apt to defeat its own ends; owing to the tremendous blast from modern weapons a good many designs which appear very formidable on paper will probably be found in action to be gravely defective owing to gun interference. On a limited deck space comparatively few heavy pieces can be advantageously mounted, and no doubt the American designers have exercised a wise restraint in limiting the number of 12-inch pieces in order to obtain the immense advantage which accrues from ease to employ every weapon on either broadside. This is a feature which was introduced first into the British *Indomitable* class of cruiser battleships which have a broadside of eight 12-inch guns each, the same as the *Dreadnought*, although the *Dreadnought* actually carries two more 12-inch weapons. The United States Board of Construction claim that their design is the best which has yet been evolved, and immediately the general details were submitted to Congress orders were given this spring for two battleships to be laid down. The principal characteristics of the vessels are:—Length on load waterline (about), 510 feet; breadth, extreme at load waterline (about), 83 feet 3 inches; displacement on trial, not more than 20,000 tons; mean



BATTLESHIP ALABAMA. THE ILLINOIS AND WISCONSIN ARE IN THE SAME CLASS.

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THE PROTECTED CRUISER CHARLESTON

draught to bottom of keel at trial displacement, 27 feet; total coal bunker capacity (about), 2,300 tons; coal carried on trial, 1,000 tons; feed water carried on trial, 66 tons; speed on trial, 21 knots. Armament: Main battery, ten 12-inch breech-loading rifles; secondary battery for repelling attacks by torpedo craft, fourteen 5-inch rapid-fire guns; four 3-pounder saluting guns; four 1-pounder semi-automatic guns; two 3-inch field pieces; two machine guns, calibre .30; two submerged torpedo tubes.

The hull is protected by a water-line belt of armour 8 feet in width, whose maximum thickness is 11 inches and whose cross section is

uniform throughout the length of the belt. This belt armour gives effective protection to the boilers, machinery and magazine spaces, and, as the Secretary of the Navy has pointed out, most important of all for vessels of this type whose centers of gravity are necessarily very high, affords, in connection with the casemate armour and extensive compartmental subdivision, a reasonable assurance of the maintenance of the stability of the vessel under battle condition. The side above the main belt armour is protected by armour 7 feet 3 inches wide and a maximum thickness of 10 inches. This armour is likewise of uniform cross section throughout and, in length, is only slightly less than that of the main waterline belt armour. Above the main casemate armour, amidships, the side is protected by armour 5 inches in thickness, which affords protection to the smoke pipes, the major portion of the secondary battery of 5-inch guns, and the hull structure. Suitable athwartship and diagonal bulkheads are worked at the extremities of the belt and casemate armour, and a protected deck of suitable thickness is provided throughout the length of the vessel.

With particular reference to the offensive qualities of the proposed design, it is claimed that the arrangement of the main battery guns is such as to permit a broadside fire 25 per cent. greater than that of the broadside fire of any battleship now built—the *Dreadnought*—or, so far as known, under construction, and the average elevation of the axes of these guns above the waterline is believed to be greater than that of any known battleship, thus affording a distinct advantage in long-range firing under all conditions of weather.

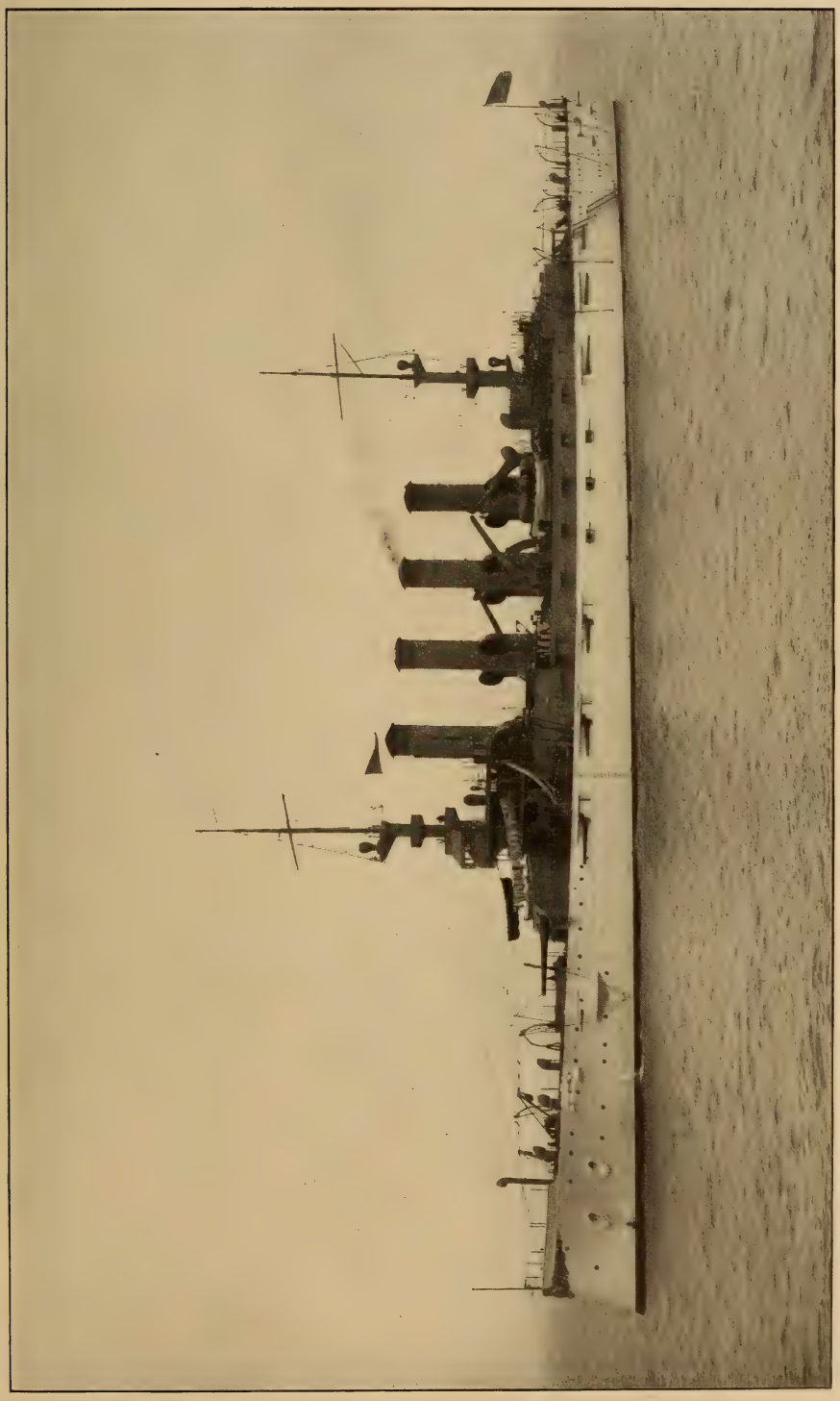
As to the defensive qualities other than those dependent upon armour protection, the designers have provided for an arrangement of the interior structure of the vessel to give the maximum degree of protection to all vital portions by means of unusually effective compartmental subdivision, so that, in conjunction with the armour protection the defensive qualities of this vessel "are believed to be distinctly superior to those of any battleship hitherto designed." This is Mr. Dehlecrat's opinion of the American designers. In this connection it is urged by the American authorities that the percentage of weight allotted to hull and armour is markedly greater than the percentage of such weights allotted to similar purposes in the largest battleships now in existence—again the British *Dreadnought*—and the actual total of such weight is, in the proposed design, approximately 3,000 tons greater than in the largest battleship so far built. The design provides for a trial of 21 knots. Provision is also made for the storage of a large amount of fuel without in any degree reducing the capacity of the coal bunkers.

These two vessels are veritable *Dreadnoughts* with a heavier broadside, a somewhat more considerable burden of armour, as high a speed, and probably a rather better radius of action. They will prove most formidable acquisitions in the defense of American interests and, owing to the outcry which has been raised as to the delay of naval construction in the United States and the long period which was devoted to the evolution of this design, it is confidently anticipated that these vessels will be constructed with none of the variations which have retarded other ships. One of the vessels has been given to the Newport News Shipbuilding & Dry Dock Company and the other to the Fore River Shipbuilding Company. The tenders indicate that these two ships will be among the cheapest in proportion to their size ever built for the American fleet. The tenders were 10 per cent. lower than the official estimate. The vessels will be identical, except for the fact that the battleship to be built by the Fore River Company will probably have Curtis turbines installed, while the Newport News ship is to have turbines of the Parsons type.

CRUISERS.

In the past seven years Congress has made notable additions to the number of armoured cruisers in the fleet. For its strength in battleships the American Navy is far less adequately supplied with cruising ships than is the case in the British and French fleets, but, on the other hand, in ships of the larger class is rather better off than Germany. While Germany possesses, built and building, ten first-class cruisers, the United States had fifteen built or building, and ten of these rank with the finest swift armoured ships in commission in any fleet in the world. The fleet has lately been strengthened by six vessels of the *California* class of 13,680 tons displacement each, a speed of 22 knots, a coal capacity equivalent to 12,000 miles at 10 knots, an armament of four 8-inch and fourteen 6-inch quick-firers, allied with a complete armour belt varying in thickness from 6 inches to 3½ inches, allied with a 3 or 4-inch deck and very complete protection for the guns. In the four later cruisers to be put in hand, the *Washington, Tennessee, Montana* and *North Carolina,* a further advance was made in concentration of gun fire by mounting four 10-inch in association with sixteen 6-inch guns, and provision was made in these four vessels for much larger fuel supply. Although these latest cruisers compare very favourably with the vessels of this type to be found in European fleets, they are slower and less heavily armed than the latest type of British vessels under construction. The American Navy also includes three ships of the *St. Louis* class, with a rate of steaming of 22 knots also, which are so heavily protected as to come practically within the classification of armoured cruisers. She also possesses three second class cruisers and fourteen small, but useful, ships for scouting. The most recent additions to the last class are the *Birmingham, Chester* and *Salem,* now under construction, which on a displacement of 3,750 tons are expected to steam 24 knots an hour. In view of the attention which was being devoted to this type of cruiser, the American design is of special interest. It is evident that the Navy Department has learnt the striking weakness of the eight scouts already built for the British fleet, for in the American vessels provision has been made for more than twice the coal capacity of the British scouts. The general details of these three vessels may be thus summarized:—Length between perpendiculars, 420 feet; breadth, moulded, 46 feet 8 inches; draught, fully loaded, 19 feet 1½ inches; depth amidship, moulded, 36 feet 5 1-16 inches; displacement, fully loaded, 4,640 tons; displacement on trial, 3,750 tons; draught on trial, 16 feet 9½ inches; total coal capacity, 1,250 tons; coal on trial, 475 tons; feed water, total, 100 tons; feed water on trial, 50 tons; maximum speed, average of four hours' run, 24 knots; steaming radius at 10 knots, about 6,250 nautical miles; steaming radius at full speed, about 1,875 nautical miles; maximum indicated horse-power, main engines, estimated, 16,000; indicated horse-power, auxiliaries, 400 horse-power. In planning the structural details the greatest care has been exercised to provide a hull which shall combine with lightness the strength and stiffness necessary to successfully withstand the severe shocks which the vessel may be called upon to undergo, and particularly attention has been paid to the longitudinal strength of the vessel and to the strength of the water-tight bulkheads, in order that they may be able to withstand the pressure due to the flooding of any compartment, and thus avoid endangering the vessel as a whole. The hull is built of steel throughout, and she has an inner bottom, so that the vessel will be well protected from injury in case of grounding.

Five decks, designated as forecastle, main, berth, orlop and platform, respectively, are provided, the



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UNITED STATES CRUISER WASHINGTON. THIS ALSO REPRESENTS THE TENNESSEE, MONTANA AND NORTH CAROLINA.

main and berth decks being continuous from stem to stern. Nickel steel protection of 80 pounds per square foot is worked on the shell plating for the length of the machinery space, including the dynamo room, extending from about 3 feet 4 inches below the waterline to about 9 feet 6 inches above, abreast the engine and dynamo rooms, and 6 feet 6 inches above, abreast the boiler rooms. At the forward end of the machinery space and the after end of the dynamo room, partial athwartship bulkheads of 40 pounds nickel steel will be fitted of the same length of the adjoining side protection. Nickel steel protection will also be fitted in wake of the steering engine.

The battery, consisting of two 5-inch and six 3-inch rapid-fire guns and two 21-inch submerged torpedo tubes, is a particularly good one for such a vessel.

Two submerged torpedo tubes of the side-loading type, with all necessary accessories, will be installed in the torpedo room forward, one on each side. Four torpedoes for each tube will be carried.

The engines will be of the vertical, twin screw, four-cylinder, triple-expansion type, located in separate compartments, of a combined indicated horse-power of 16,000, arranged for outboard turning propellers when going ahead. The steam pressure in the high pressure cylinder will be 250 pounds. The necessary auxiliaries and accessories will be provided in accordance with the practice of the Bureau of Steam Engineering.

There will be twelve water-tube boilers of the "Express" type, placed in three watertight compartments, with a total grate surface of 693 square feet, and a total heating surface of 37,080 square feet. The working pressure will be 275 pounds per square inch. The steaming capacity will be such that all the steam machinery can be run at full power with an average air pressure in the firerooms of 5 inches of water. Four smoke pipes, each 75 feet high above the base, will be fitted. An evaporating and distilling plant, capable of evaporating and condensing 16,000 gallons of water per day, will be installed, and a refrigerating plant of 2 tons capacity will also be fitted.

Probably these vessels will be fitted with the Babcock & Wilcox boilers, which have hitherto been first favourites in the navy of the United States, upwards of forty battleships and cruisers having been already installed with this successful type of steam generator.

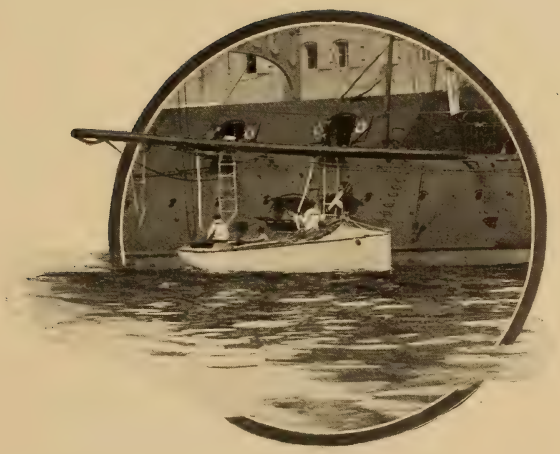
TORPEDO CRAFT.

In proportion to the size of the fleet of the United States, relatively little attention has been given, in contrast with European fleets, to the development of torpedo craft.

While Great Britain has built and is building 151 torpedo boat destroyers, Russia 97, Germany 73, and France 65, the United States has only 25 of these vessels, including the three of last year's programme and the two included in the programme of the present year. The main attention of the Navy Department has been concentrated upon armoured units, and no one who studies the American fleet and its geographical position can doubt that great wisdom has been shown in resisting the temptation to build a large number of small vessels of limited utility. The Navy Department has provided the fleet in the past ten years with a series of useful ships of upwards of 400 tons displacement, ships with good radius of action, high speed, and for the most part with an armament which compares favourably with that carried in most British destroyers, though it is inferior to the provision made in the latest Japanese vessels. While the American destroyers are given two 14-pounder guns and five or six 6 pounders, Japan has built thirty-four ships of approximately 375 tons, each mounting six 12 pounders. No doubt in accordance with the lessons deduced from the

war in the Far East, the armaments of the future American destroyers will be considerably heavier and will probably be found, as in the case of the Japanese ships, to be of one type of gun.

The building of torpedo boats for the American navy has entirely ceased during the present century, and there are only thirty-two of these vessels, of which twenty-six are classified as first class. On the other hand, considerable attention has been devoted to submarines. A long series of experiments has been made with a view to adopting a type of ship meeting with the approval of American naval officers, and at last the vote has gone in favour of the *Octopus* type. Within the next twelve months a very large sum will be devoted to the construction of submarines, which are the torpedo boats of the future.



THE AUTOMOBILE SITUATION IN FRANCE

By Jacques Boyer

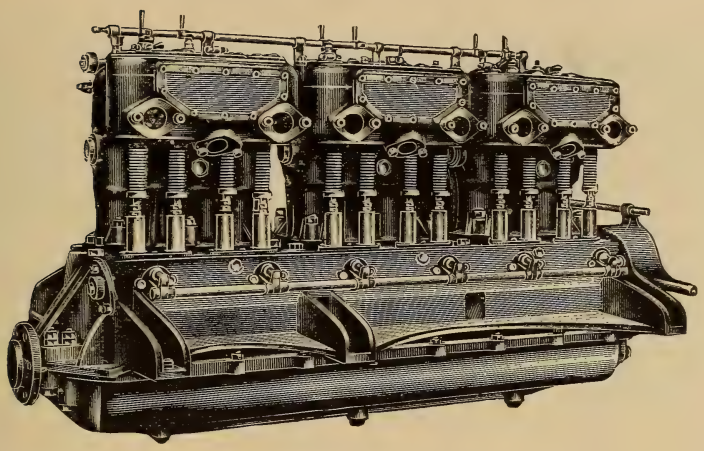
AT the present time the automobile industry of France is undergoing an economic crisis. A comparatively short time ago investors in Paris considered the shares of automobile manufacturing companies as of excellent value, and capitalists desirous of securing remunerative dividends were advised to place their funds in these enterprises. The enormous success of certain French machines and the large fortunes gained by their proprietors in a comparatively short time fully justified these opinions. The rapid multiplication of manufacturers and the inevitable overproduction naturally led to a number of disappointments, and the exaggerated impression given to these affairs in the financial world led to a crash in the values of automobile securities. This, however, is but a passing crisis; the present pessimism of to-day does not fairly represent the actual situation any more correctly than did the excessive optimism of yesterday. The truth, as usual, lies between the two extremes of opinion.

Certain builders of automobiles have gone too fast. Intoxicated by the unexpected development of their business, they have installed manufacturing plant much greater than necessary and, in consequence, find themselves overstocked. Nevertheless, it would be absurd to consider this department of French industry as declining. Although there have been individual failures, statistics (always more reliable than mere speculative opinion) attest the fact that the automobile industry still plays an important part in the commerce of France. During the year 1907 the value of automobiles exported up to October exceeded by six million francs that of 1906. At the close of 1906 there were in actual operation in France 14,555 automobile vehicles of more than two places, and with an average power of 15 horsepower. No speculation can controvert the meaning of these figures.

It is our opinion that, although the foreign market is necessarily diminished by reason of the development of competitive establishments, the industry has nothing to fear. If the French designers of automobiles apply themselves to meet, on the one hand, the requirements for industrial and agricultural automobiles by producing sturdy vehicles, easily managed; and, on the other hand, the demand for light, economical carriages for physicians, commercial travellers, notaries, and other professional men; if, in a word, they democratize what is now a luxury of transportation, fortune will once more shine upon them.

Bearing in mind this development, evidences of which are already becoming apparent, we shall give a rapid review of the present status of automobile construction in France, with especial reference to the propelling machinery.

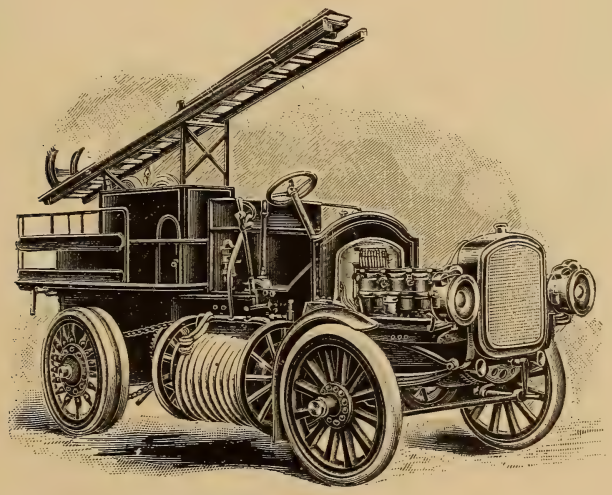
In France there has been for some time a tendency toward standardization, at least along certain general lines of construction. There is no longer apparent a tendency to transform each year the models of the previous year. Thus we may notice certain tendencies which have become apparent during 1907. Among these may be noted the appearance, or rather the reappearance, of the six-cylinder motor. Originally of French design, the six-cylinder motor, fol-



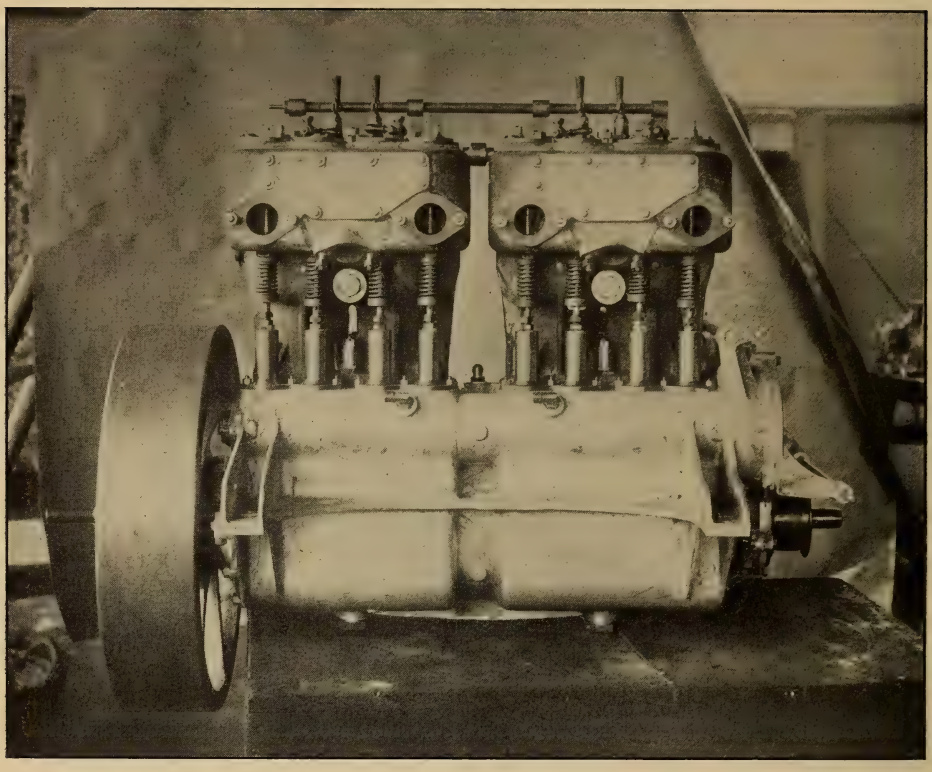
BRASIER SIX-CYLINDER MOTOR, MODEL OF 1907

lowed by some of eight cylinders, appeared several years ago, but without any especial success for either type. Then the six-cylinder design crossed the Channel, and some three or four years ago it was adopted in Napier touring cars. Revived by this trip to England, the six-cylinder motor made a sensational return at the last Paris Salon.

Motors of this kind, which are nothing more than the four-cylinder motor with two cylinders added, offer certain advantages in performance; but opposed to this there appears a greater mechanical complication. For example, in the six-cylinder Brasier, we find the same general arrangement as appears in the four-cylinder engine of the same builders. The motors are offset with respect to the crankshaft, an arrangement which is considered as an improvement both as regards wear and balancing. The admission and exhaust valves are placed on the same side of the motor, and operated by a single cam shaft, the cams being formed in one piece with the shaft. The ignition is effected by magneto and in-



DELAHAYE AUTOMOBILE FIRE ENGINE, BUILT IN 1907 FOR THE PARIS FIRE DEPARTMENT



BRASIER FOUR-CYLINDER MOTOR, MODEL OF 1907, SHOWING VALVE SIDE

terrupters, the shaft being arranged at one side by the upper part of the cylinders. This shaft carries the cams controlling the interrupters, so that, whatever the speed of the motor, the ignition occurs promptly and uniformly.

The four-cylinder motor is used for the great majority of French automobiles from 12 to 60 horse-power, and it is also beginning to be employed for lighter vehicles.

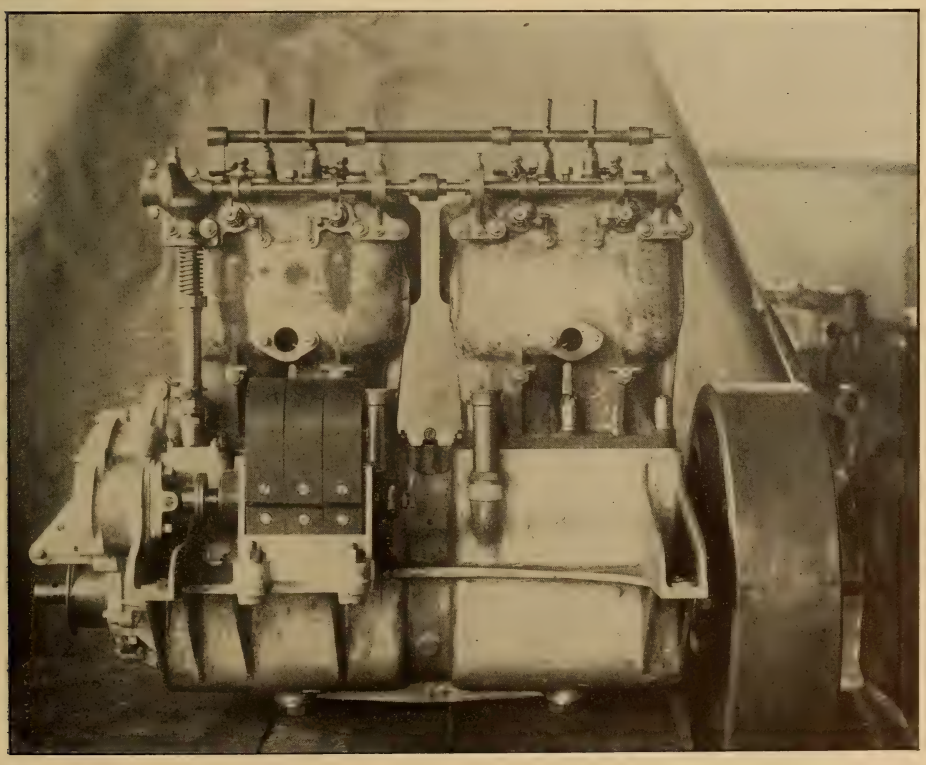
Brasier, Grégoire, Renault, and other builders are constructing automobiles with four-cylinder motors of low power. Some two-cylinder cars and a number of single-cylinder machines are made for sizes below 9 horse-power, and a few three-cylinder machines survive.

The position of the motor on the chassis appears to have become definitely determined; it has receded to a point where the radiator is directly above the axle. Separate cylinders have been almost abandoned, this arrangement being retained, it is true, by de Dion and by Panhard and Levassor. In nearly all machines the cylinders are cast in pairs. Dietrich and Charron go still further and make the four cylinders in a single casting. This arrangement may be all right for use in city vehicles, and where the slight gain in space is desired, but we do not believe it is justified for road cars. The cost of four cylinders in one piece exceeds that of two groups in pairs, and in case of a breakage the expense of repairs is much greater. The single casting may, therefore, be considered advisable for city carriages, although not justified for touring cars. Some French builders take another view of this question; they cast the four

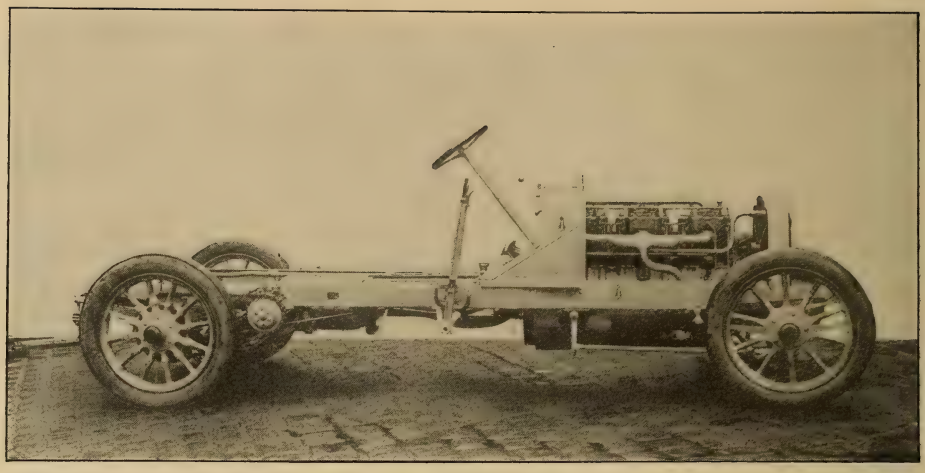
cylinders in one piece for motors below 12 to 15 horse-power, and make them in pairs for the higher powers.

Among other evidences of standardization in French motors we may note the almost complete disappearance of the horizontal type. Almost the only design seen is that with vertical cylinders, except that the V arrangement, with two cylinders, is used with some light vehicles. This arrangement is also employed in the Antoinette motor with twenty-four cylinders, designed for aeronautical purposes. This apparatus weighs 700 kilogrammes, measures 3 metres in length, and develops 360 horse-power; corresponding to a weight of 1,543 pounds, or only 4.29 pounds per metric horse-power, or about 4.35 pounds per British horse-power. Three motors of eight cylinders each are arranged end to end and assembled with bolts. The cylinders are 150 millimetres bore and the same stroke, and there is a double ignition system.

The Gobron motor, with opposed pistons, offers certain features of interest. Each cylinder contains two pistons between which the explosion takes place. The lower piston operates the crank by a connecting-rod in the ordinary manner, while the upper piston is connected to a crank beyond the line of the cylinder. In this way the crankshaft is subjected to two forces acting in opposite directions, producing a perfect balance. Another motor, that of Bondreaux-Vernel, has a double piston with explosion chambers and compression chambers separated. The pistons are of different diameters, forming two parts, with a telescope action, permitting a double effort upon the same crank. The separation of the compression chamber from the explo-



BRASIER FOUR-CYLINDER MOTOR, SHOWING ARRANGEMENT OF MAGNETO

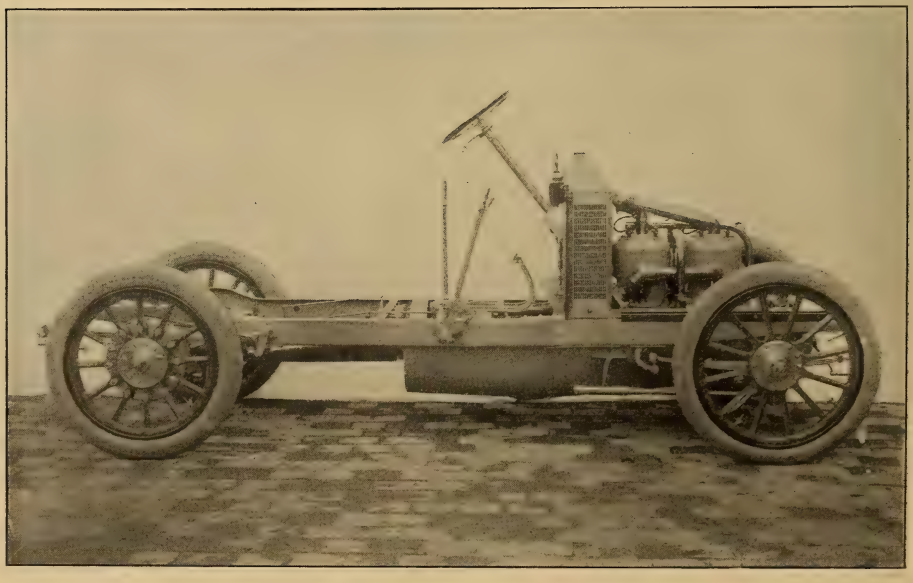


MORS CHASSIS, MODEL OF 1907

sion chamber, as well as the arrangement of the latter in a contracted space, assures a prompt ignition, together with a minimum loss of heat by cooling.

The majority of the French motors have the crankshaft directly under the centre line of the cylinders. Some builders have followed the example set by Mors in 1905 in offsetting the crankshaft. Brasier and Delaunay-Belleville adopted this arrangement in 1906, and they were followed in 1907 by Niclausse. The practice of such important firms should be considered in favour of such an arrangement.

In the ordinary arrangement, the piston being at the top of the cylinders at the moment of the explosion, the connecting-rod and crank are in a direct line, and there is no

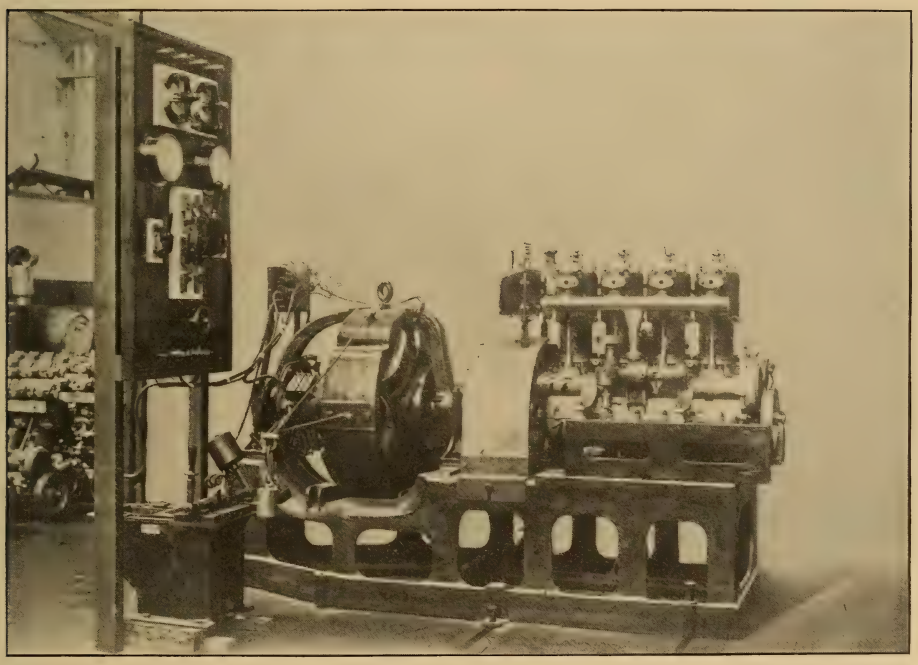


RENAULT CHASSIS WITH FOUR-CYLINDER MOTOR OF 16-20 HORSE-POWER, 1907 MODEL

oblique action on the latter, a condition which cannot be avoided in motors which are not offset. With the offset shaft there is less tendency to pound, and consequently less wear. The crankshaft should not be offset too far, or there will be an excessive obliquity on the return stroke. Experience has shown that the best results are obtained when the shaft is offset one-sixth; that is, when the distance from the centre line of the cylinder to the axis of the crankshaft is not more than one-sixth of the length of the stroke of the engine.

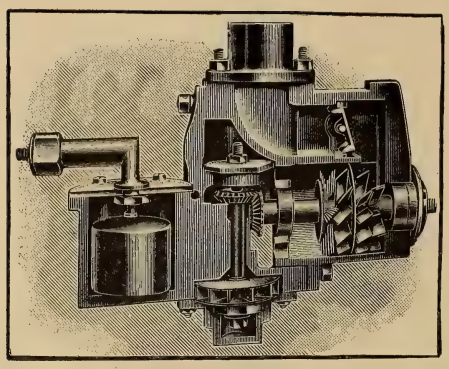
The use of the high-tension magneto is being more and more generally adopted, even on small vehicles. In this respect French builders have gone abroad, many of them using the Simms-Bosch magneto. In other respects designers are endeavoring to simplify the ignition apparatus. The magneto is attached by two lugs provided with bolts fitted with thumb nuts, so that it may easily be removed. In other respects the Simms-Bosch magneto is readily controlled and adjusted. The duplication of the ignition apparatus is becoming less and less general, in view of the reliability of the magneto. The idea of the double ignition was to avoid operative difficulties, but it often failed to accomplish this end.

With regard to carbureters, those of purely mechanical action predominate, and the automatic type, as Commandant Krebs predicted, have fallen to the rear.



PANHARD & LEVASSOR 24-HORSE-POWER FOUR-CYLINDER MOTOR CONNECTED TO BRAKE AND DYNAMO IN THE TESTING ROOM

The greater number of these devices control the mixture by an automatic or mechanical variation in the quantity of air admitted. The Japy carbureter of 1906 is an interesting and novel form. In nearly all carbureters the action becomes irregular when the rotative speed of the motor exceeds the normal, even though the openings for the admission of air are increased, the flow of the fuel often continuing independently of the



SECTION OF THE JAPY CARBURETER

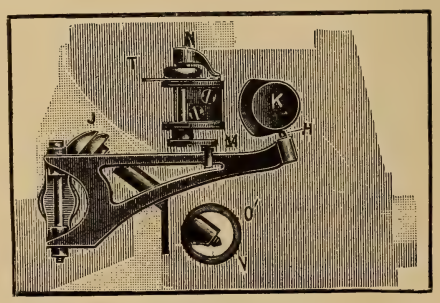
aspiration of the air. The new device is controlled mechanically by a shaft connected to any rotating part of the motor. A pair of bevel gears transmits the motion to a centrifugal pump which delivers the essence to the float reservoir. The air enters the carbureting chamber through two orifices, one of which is reserved for the admission of hot air. The essence is delivered by the pump through a passage in which the flow is controlled both by the speed of the centrifugal pump and by a valve obstructing more or less the opening to the cylinders. The air and the essence pass into a chamber containing two small fans, one constructed of small rods and the other made with blades, their rotary motion effectually mixing the liquid and the gas. The delivery is proportional to the speed of the motor, since the pressure of the liquid and the admission of the air are both dependent upon the speed. This action is shown in the illustration, in which the cam *K* operates the lever *J* and needle valve *V* through the contract point *H*. The carbureter is controlled by turning the arm *N* around the dial *T*, where it can be clamped in any position, the stop *M* then determining the maximum opening of the needle valve. A Japy carbureter attached to a Barriquand and Marre motor of 25 horsepower showed the following relation between power and speed:

Speed.	Power.
900 revolutions.	32.5 horse-power.
1,050 revolutions.	36.0 horse-power.
1,175 revolutions.	38.0 horse-power.
1,350 revolutions.	43.2 horse-power.

These figures show that this improved type of carbureter is worthy of the attention of designers. The six-cylinder motor demands no special modification in the carbureter.

French builders continue to make various modifications in the design of clutches. A number of manufacturers, including such firms as Renault Gobron Dietrich and Peugeot, remain faithful to the cone clutch. A number of other types are in use, however, including metallic clutches with double or triple plates, clutches with expanding segments, spirals, friction discs, etc. The reader may wonder at this multiplicity of forms when the cone clutch gives such excellent results. The principal objects sought are doubtless a reduction in inertia, facilitating the changes of speed, besides a diminution in the tendency to heat, and an avoidance of the necessity for excessive lubrication in case of prolonged friction.

Chain transmission still has its partisans, as also has the method of shaft driving, with universal joints. Manufacturers are divided on this point, each advancing excellent reasons for his opinion, and it is difficult to persuade the advocates of either type to make a change. Shaft driving appears to show a higher efficiency, but, on the other hand, the proportion of dead weight not carried on the springs is much greater with the shaft than with chains. A



CONTROL OF THE JAPY CARBURETER

PANHARD & LEVASSOR MOTOR OMNIBUS, 1907 MODEL

forged iron axle weighs about 20 kilogrammes, while the weight of a shaft transmission gear may reach 100 kilogrammes. Besides these two principal systems, there are transmissions using worm gearing, belts, friction discs, etc.

Comparatively few modifications have recently been made in the design of radiators. We may notice one form, called the "Triplex." This apparatus resembles a fan, the blades being formed of copper tubing, fixed upon two pipes, one at the centre of

DELIVERY WAGON, 1907 MODEL, WITH FOUR-CYLINDER MOTOR OF 8 HORSE-POWER

TRUCK FOR HAULING MERCHANDISE. PANHARD & LEVASSOR, MODEL OF 1907

rotation, the other at the periphery. The water coming from the cylinder jackets enters the tubes at their bases, and the radiator, being kept in rotation by the motor shaft, the water is driven through the tubes by centrifugal force. A pump arranged in the hub of the apparatus draws the water from each wing, and delivers it to the reservoir. The honeycomb type of radiator is being continually improved. Many of the early designs of this kind were easily broken, but those of recent construction are as sturdy as the sectional types.

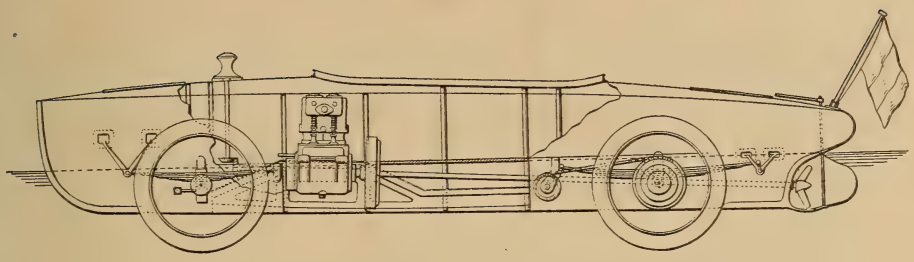
Nearly all French automobiles, even of the lightest type, now have mechanically operated valves. In some instances the automatic valves as originally designed by De Dion are used. There is, however, a general tendency to increase the diameter of the valves, in order to render more powerful what may be termed the lungs of the motor.

So far as the chassis is concerned, the French builders seem to prefer the use of pressed sheet steel. Among the few exceptions to this rule we may mention the firm of Panhard as one remaining faithful to the use of wood reinforced with metal. In nearly every case the material preferred is nickel steel.

Various attempts are being made to improve the lubrication. Such establishments as Delaunay-Belleville and De Dion are using forced lubrication systems. Automatic lubrication is being extended from the motor to all parts of the chassis. In many French automobiles the parts not readily accessible to the chauffeur are arranged to be lubricated continuously on the splash system.

Nearly all vehicles are now provided with expanding segmental brakes. The most recent improvement in connection with tires is the removable rim, of which the "Celer" is among the best known. This system consists of a fixed metallic rim, attached directly to the wooden rim of the wheel, and a movable metal rim to which the tire, previously inflated, is attached. An elastic band is used to attach the movable to the fixed rim, and the operation of removing a rim and tire and replacing it with another takes less than a minute.

A number of French builders are



SECTIONAL VIEW OF THE RAVAILLIER BOAT-CARRIAGE

turning their attention to the construction of heavy commercial vehicles. Among these may be mentioned the firms of Brillié and of Panhard, who have undertaken the manufacture of motor omnibuses. The chassis of these vehicles, as well as of the trucks for merchandise, resemble closely those of large touring cars, except that the parts are made stronger and heavier. The Mors truck or lorry has a chassis which shows evidence of careful study. In these vehicles the motor is placed under the seat occupied by the driver. In this connection we may mention the Scotte traction system, now more than ten years old, in which a steam motor car hauls trailers loaded with 15,000 to 20,000 kilogrammes. More recently the Delahaye Company has built a vehicle weighing 5,000 kilogrammes for the service of the Paris Fire Department, this machine having a motor of 45 brake-horse-power. The especial peculiarity of this vehicle lies in the brakes, there being no fewer than five powerful devices, two on the rear wheels, two on the chain pinions, and one on the differential. This machine can carry sixteen men; the pump is placed in the rear, and is driven by a shaft, which may be thrown instantly into gear with the motor shaft close to the fly-wheel.

The Purrey automotive is a special vehicle intended for operation on railway tracks. This machine is equipped with a steam engine and special boiler of the Purrey type, and carries sufficient water and fuel for a run of 60 to 100 kilometres. One of these convenient vehicles can carry seventy passengers, attaining speeds as high as 90 kilometres, or about 56 miles, an hour; and for local service, or to replace special emergency trains, these automotives are found extremely serviceable.

We cannot conclude this sketch of the automobile situation in France in 1907 without mentioning the amphibious automobile of M. Ravaillier, which does not belong to any of the preceding classes, since it may either navigate in the water or roll on land. This "boat-carriage," which was officially tested on June 7, 1907, in the presence of M. Barthon, the French Minister of Public Works, consists of a hull or body of sheet steel, riveted to a structural framework, and carried upon sheet-steel wheels by spring supports. The axles pass through watertight tubes, which traverse the hull, the whole being well designed by M. Gustave Pitre, the able engineer of the Maisons-Laffitté. The motor, built by M. Goutallier, of Vincennes, is placed forward. It operates two distinct sets of mechanisms by means of disc clutches. One of these includes a speed-changing gear, which transmits motion, by means of chains, to the two rear wheels, the chain pinion shaft passing through two stuffing boxes. There are three forward speeds and one backward. A clutch pedal, pedal to a brake on the differential, a speed-changing lever, and a lever to brakes on the rear wheels. A hand-wheel steering gear, of which the shaft passes through a stuffing box, operates the front wheels in the ordinary manner.

THE RAVAILLIER MACHINE ON LAND

THE RAVAILLIER MACHINE ENTERING THE WATER

The second driving mechanism is formed by the prolongation of the change-speed shaft, connected by a clutch to a screw propeller placed at the rear of the hull. The reversing mechanism is controlled by a lever placed at the left of the pilot. The steering hand wheel acts simultaneously upon the forward wheels and upon the rudder placed behind the propeller. The windlass, placed forward, is operated by worm wheel gearing, which is driven by belt connection with the motor. The rear wheels, propeller and windlass may be operated simultaneously or independently.

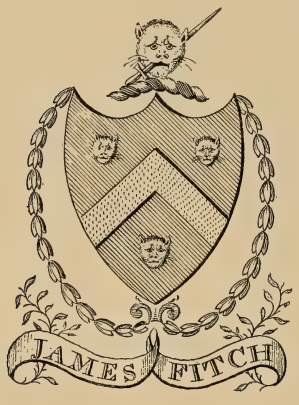
The Ravaillier operates equally well on land or in the water. A number of experimental tests have given speeds of 35 kilometres an hour on land, and 9 kilometres in the water. No change is required in the operation of the vehicle; it can leave the road and plunge directly down a grade into the water. When navigating, it shows excellent stability, and with grades of less than 15 in 100 it can leave the water under the propulsion of the rear wheels if the ground is sufficiently hard. For steeper inclines, or in case of soft ground, the windlass is used, the cord being attached to a post or other fixed point on shore. The new automobile boat is provided with a bilge pump, an anchor, a life buoy, and a pair of oars, to enable the shore to be reached in case of derangement of the machinery.

This ingenious invention, which is about to be exhibited in the United States, should be most serviceable for tourists and explorers, enabling them to traverse land and water in one and the same automobile vehicle.

WHO BUILT THE FIRST STEAMBOAT?

By C. Seymour Bullock

In our issue for September we gave some account of the early experiences of Robert Fulton, in the development of the steamboat, and this was followed in October by a paper upon the work of Symington and his associates in Great Britain. As a fitting conclusion to the topic in this, the centenary year of the practical introduction of steam power in navigation, we here have a review of the work of a number of early mechanics and inventors, the whole showing very clearly that the application of steam to the propulsion of vessels was in many minds about the same time, and like other great advances in mechanical science, it was evolved as a natural consequence of the progress in the departments of engineering of which it formed a part.—THE EDITOR.



THE steamboat of to-day is not a creation, but an evolution. Running back for more than a hundred years are the time-marks, like so many mile-stones, that trace the way by which the earliest experiments have been developed into the final success.

Among those who in America first gave thought to the production of a steamboat was John Fitch, of Connecticut, who not only proposed but actually built a steamboat, and went so far as to suggest that he could build for the "Great Lakes" a boat that could be run over the ice in the winter and drop into the open reaches of water that he had discovered were to be found in Lake Erie—even in the coldest weather—using for propulsion the side-paddle-wheels, which were to be spiked around the outer rim for use on the ice. Perhaps somewhat earlier than John Fitch in the actual application of steam as a motive power for navigation must be mentioned the name of William Henry, of Pennsylvania. This genius, without ever having heard of a steam engine, built a boat to be propelled by the power of "elastic vapour," and actually ran it on the river near his home.

With Fitch and Henry must be mentioned the name of James Rumsey, who so far succeeded in producing a steamboat, or some other kind of a boat, as to get the endorsement of George Washington, then President, and thus subsequently gained for his son a medal, voted by Congress to show the nation's appreciation, while it is probable that the Rumsey boat was not a steamboat at all.

Later, there were William Longstreet, of New Jersey, who went to Georgia and built a boat on lines that had never been used before nor been adopted since, and Samuel Morey, of Orford, Conn., who built a steamboat on which he sailed from Hartford down the Connecticut River, through Long Island Sound to New York City and back again, and so favourably impressed Colonel Stevens, Chancellor Livingston and Nicholas Roosevelt that, after sailing on his boat, they proposed to engage with him in a steamboat-building enterprise, and then forgot that there had ever been a man whose little craft was the incentive for their later attempts to master the wind and tide.

Besides these there are Elijah Ormsbee, of Rhode Island, who built an engine and installed it in the longboat of the ship *Abigail,* borrowed for the occasion from Clark & Nightengale, the ship's owners, and furnished it with steam from a copper still loaned by Captain Ephraim Bowen; and Oliver Evans, of Pennsylvania, the builder of the original high-pressure engine of the type that has continued to this day wherever swift currents are to be met or great speed attained. One other name is prominently brought forth, that of Nicholas Roosevelt, whose heirs claim that to him belongs the credit of having proposed to Robert Fulton the use of the paddle-wheels at the side of the boat, without which the *North River of Clermont* must have proved an absolute failure.

Space is too limited to take up in detail these several claims, but it will prove not without interest to glance at them in the passing. Among the records of the American Philosophical Society is an entry for December 2, 1785, as follows: "At a special meeting of the Philosophical Society, John Fitch was personally introduced to the members." In the meeting that night was William Henry, who outlined to Fitch his experiments with steamboats on the Conestoga River. Fitch had come to the meeting to consult with the members about his proposed steamboat, and had especially desired to meet the man who had already made a success of what to him was as yet a problem. We, therefore, give to William Henry with his undisputed claim the first place on the list of successful steamboat builders in the United States.

From all that is left of the attempts made by James Rumsey there is absolutely nothing to prove that he ever built a steamboat in the United States. The boat for which he had Washington's endorsement seems not to have been a steamboat at all, but rather a peculiarily rigged long-legged thing that was haunched over falls and through rapids by poles that rested on the bottom of the stream. The much-written-of endorsement is in these few words: "I give it as my opinion that he has discovered the art of working boats by mechanics and small manual assistance against rapid streams." Later, however, Rumsey went to England and there built a boat on the water jet idea, which was not at all original, having been described by Franklin as a sugestion of the younger Bernouilli. This attempted steamboat proved to be a failure, as the trunk could not be made to withstand the pressure necessary to its success.

For Samuel Morey the claim is advanced that he built a successful steamboat, and that the principles incorporated in its engine were entirely original and became the basis of the claims with which Sullivan contested the rights of the Fulton-Livingston Company to the exclusive navigation of steam craft upon the Hudson. Much of the correspondence that passed between Morey and Professor Benjamin Silliman, of Yale College, is said to be still in existence. In a letter to Cadwaller Colden, the chief counsel, and later the biographer of Robert Fulton, Sullivan, the coworker of Morey, says:

"Morey's revolving engine was recognized by an act of the Legislature and the term of duration (of a grant to use it on the Connecticut) conditionally extended. It is indeed the mode of using steam power not only best adapted to the Southern rivers, where the great bulk of transportation is with the current, but wherever the tide favours navigation. It had long been my design to occupy those rivers in the winter months with steamboats used on the Hudson in the summer season. We constructed a boat in Boston and made our passage to Charleston, but too late in autumn for the greatest success. We had previously built the tow-boats, so that, in fact, the same engine that you confounded with old iron towed loads of mer-

chandise up the Santee against the heavy freshets the last winter, bringing down large quantities of cotton. Is there any reason why such steamboats should not operate well on the Hudson? Was it fair to give the unfounded coloring you have to the issue of the enterprise in Connecticut? Does the speed of a vessel affect the principle, or does it depend on some proportion between the power and the load? The performance of the same engine was abundantly good in Carolina by as much increase of boiler as was requisite in Connecticut."

In 1853 the Rev. Cyrus Mann published in the Boston *Recorder* a plea for the claims of his friend, Captain Morey, whose boat he had seen upon the Connecticut as early as 1793, when it made regular trips between Orford and Fairlee. There is a model of this diminutive thing in the Town Hall at Fairlee, Vt., where it is treasured as one of the choicest ties that binds the present to the past. The boat, so says the Rev. Mr. Mann, was "scarce big enough to carry himself (Morey), the crude engine and boiler and the handful of wood needed to run it"—a fairy boat that might have been built for Mr. Paaps, of whom Dickens wrote, or for the King of the Lilliputians.

Later on Captain Morey built the larger stern-wheeled boat and made a trip to New York. Here, then, is another successful steamboat antedating the *Clermont* and, incidentally, the opening of a page in the history of "coastal steamboating" that no one has fully read. Was there a steamboat that went to sea before the *Phœnix* went out from New York Bay and cleared the capes to Philadelphia? Who can tell us anything about this little craft that venturesomely sailed out of Boston for service on the Santee?

The story of Elijah Ormsbee is not so well known. A native of Connecticut, a carpenter, he removed to Providence, and there began experimenting with steam for a motive power. He knew the difficulties of navigation, the uncertainties and delays, and had come to wonder why the same principles that were applied to the pumping of water from a mine near Cranston couldn't be made to move a boat. This led to the drawing up of a set of plans that were laid before David Wilkinson, of Pawtucket, who agreed to get out the iron work for an engine while Ormsbee should fashion the woodwork. Two methods of propulsion were proposed, the "flutter-wheel" (our present side-wheels) and the "goose-foot"—a contrivance arranged by Ormsbee and afterward used by Livingston and Fulton. After considerable debating, it was finally decided to try the "goose-foot," as it was thought to be easier of application and would not cost so much as the "flutter-wheels." In the fall of 1792 the boat was ready for its trial trip, of which the press of the day says:

"The boat went steadily through the water and arrived in safety at the lower wharf in Providence. The next day Ormsbee left in the boat for Pawtucket, to show Mr. Wilkinson the success which had attended his enterprise. After a day or two the boat came back to Providence, where it was received with astonishment. For several weeks the boat went up and down the river.

"The steam was not applied to elevate and depress the piston, as was done by Watt, but the steam was applied to raise the piston, and then, being condensed by cold water, the piston turned by atmospheric pressure. In this way the paddles of the boat were moved forward and aft. When they moved forward they closed, and when they moved aft they expanded to a width of from 18 to 22 inches."

The speed of the boat was from three to four miles an hour, and this would no doubt have been increased if the paddle-wheels had been used instead of the unique, but not very powerful, "goose-foot." Ormsbee seems to have done nothing

more at any time with his invention.

The claim of Nicholas Roosevelt is a broad one, and one that we may have some little difficulty in adjusting satisfactorily to every one. The use of paddle-wheels was not a new idea. The boats that carried the Roman army to the shores of Sicily are said to have been propelled by paddle-wheels turned by oxen. The same contrivance was used in different parts of Europe for ferryboats, with men for the motive power. We have copies of Savery's plan for turning wheels by a geared capstan. Nearly all the experimenters had tried to use paddle-wheels on their boats, and this is the method first proposed by John Fitch. Long before Robert Fulton ever thought of using steam as a motive power he had arranged a set of wheels over the side of the clumsy old scow out of which the senior Gumpf did his shooting when Robert and the younger Gumpf furnished the motive power that carried a boat over the flats where reed birds made a haunt. It was John Fitch's favourite arrangement, and he used the awkward swinging paddles only because they were patented by Henry Voight—his friend, principal mechanic, and financier. But it is more than probable that there is validity to the claim that the use of paddle-wheels upon the boat that first became a commercial success was suggested by Nicholas Roosevelt.

It is known that Chancellor Livingston had associated himself with an English engineer named Nesbit, and built a boat that had a horizontal wheel in the bottom, but it wouldn't work; and that then, with Colonel Stevens and Nicholas Roosevelt, he had tried to adopt floats or paddles at the stern of a boat, and this, too, was a failure. Insistent upon trying the wheels at the side stood Nicholas Roosevelt, who had been doing some experimenting alone, and was convinced that the only hope of permanent success lay in the adoption of this method of propulsion. The Chancellor was obstinate, and it took the added influence of Fulton to win him over to their adoption for the *Clermont,* by which was won the first place on the "honor roll." In a letter bearing the date of September 6, 1798, Roosevelt wrote:

"I would recommend that we throw two wheels of wood over the sides, fastened to the axis of the flys (fly-wheels), with eight arms or paddles, that part which enters the water of sheet iron to shift, according to the power they require, either deeper in the water or otherwise, and that we navigate the vessel with these until we can procure an engine of the proper size, which, I think, ought not to be less than 24-inch cylinder."

Later, he wrote a second letter to the Chancellor, in which he says:

"I hope to hear your opinion of throwing the wheels over the sides."

To this the Chancellor, who had schemes of his own, answered:

"I say nothing on the subject of wheels over the sides, as I am perfectly convinced, from variety of experiments, of the superiority of those we have adopted."

As will be seen by the date, this was before the days of Fulton, who seems to have not come into the plans at all until after the visit of John Fitch to Paris, where Chancellor Livingston was later stationed as Ambassador. But the question as to what arrangement should be used and how, was settled in the Chancellor's mind by Fulton's arguments, and when the first boat was built for the Seine, and later when the *Clermont* was planned, there was nothing said about horizontal wheels on the bottom. Writing to Fulton, Joel Barlow says:

"I can see that you have completely won the Chancellor over to your way of thinking about the wheels on the sides of the boat."

The last claimant to whom we shall listen before taking up the story of John Fitch is Oliver Evans, of Newport, Del. As early as 1786 Evans made application to his native State for the exclusive right to

use a steam engine in flour mills and for cutting marble. In the application he also asks for the sole franchise to run steam carriages (automobiles!) upon the roads of the State. A similar application was made the next year to the Legislature of Maryland. The attention of Evans was first directed to the expansive power of steam by a report of an evening's fun at a friend's house, where his brother plugged up the nipple of an old gun barrel, poured in a gill of water, rammed home a paper wad, and then stuck the barrel into the fire and waited for the report. The philosophy of the thing interested Oliver as much as the fun of it had interested the brother, and he at once began a series of experiments through which he came to the conclusion that the "elastic force" was irresistible. When he afterward came across a description of an atmospheric engine, he was surprised to find that no use had been made of this great principle. Want of means cut him off from further experimenting at that time, but later he turned to it again and built the first high-pressure engine in the world.

It was to Evans that Fitch outlined the plans for steamboating on the Great Lakes. In an affidavit, Evans says:

EXTRACT FROM THE OATH OF OLIVER EVANS

"When the said John Fitch was afterward setting out for the Western country he called on the said Oliver at his house and declared his intention to be to form a company to establish steamboats on the Western waters, of the advantages of which he appeared to form vast conceptions and great expectations. The said Oliver also saith that somewhere about the years 1786, 1787, or 1788 the said John Fitch informed him that he contemplated employing his steamboat on the Lakes and meant to construct them with two keels, to answer as runners, and when the Lakes should freeze over he would raise his boat on the ice, and by wheels on each side, with spikes in the rims to take hold of the ice, he calculated it would be possible to run thirty miles an hour. Also that he meant to tow boats and floats by his steamboat."*

In 1802 Evans wrote to a friend in Kentucky, telling him that he had perfected an engine for propelling boats and carriages. This letter was shown to Captain M'Keever, who at once took the matter up with Mr. Louis Valcourt, and the two decided to build a boat to ply between Natches and New Orleans. Valcourt went to Philadelphia to contract for the engine and follow its building, and M'Keever began work upon the hull. Both were taken to New Orleans and made ready for service, but by the time everything was ready for the launching, the river had "fallen" and left the boat high and dry half a mile back from the stream. What a predicament! Money gone, no credit, and the water in the river not to rise for six months! At this juncture a Mr. Donaldson, who had become much interested in the engine, came to the rescue and agreed to take it off their hands provided the two men who had come from Philadelphia to set it up on the boat would install it in his sawmill, near by, where the prevailing conditions were such that work could be done only when the river was "up." To make the best of an unfortunate turn, it was decided to take advantage of this offer, and the giant that was to have overcome the swift currents of the Ohio and the Mississippi was set to sawing wood, turning out 3,000 feet of lumber in twelve hours. Lumber was selling at this time for fifty and sixty dollars a thousand feet, and no attempt would have been made to put the engine back in the boat even if it had not been destroyed by some ignorant wood-choppers, who feared that it

* Original in Congressional Library, Washington, D. C.

might cut them off from a source of livelihood.

Two years later Evans built for the Board of Health of the city of Philadelphia a steam dredge that was used for cleaning out the docks. This dredge was built a mile and a half away from the water, and when it was to be delivered to its owners two axles were placed beneath the body, the wheels were geared up with its engine, and the strange amphibious thing trundled through the streets to the Schuylkill, where the wheels were removed and the engine connected with a wheel at the stern by which the boat was to be propelled. Writing at this time, Evans said:

"The time will come when people will travel in stages moved by steam engines from one city to another almost as fast as birds fly, fifteen or twenty miles an hour. Passing through the air with such velocity, changing the scene with such rapid succession, will be the most rapid, exhilarating exercise. A carriage (steam) will set out from Washington in the morning, the passengers will breakfast at Baltimore, dine at Philadelphia and sup in New York the same day. To accomplish this, two sets of railways will be laid, so nearly level as not in any way to deviate more than two degrees from a horizontal line, made of wood or iron, or smooth paths of broken stone or gravel, with a rail to guide the carriages so that they may pass each other by night as well as by day. Engines will drive boats ten or twelve miles per hour, and there will be many hundred steamboats running on the Mississippi."

When we come to the story of John Stevens—for we must say something of the achievements of this pioneer and long-successful engineer—we have to deal with one of the representatives of a family that has been so intimately connected with all the improvements that finally made steamboating commercially successful that there would be honors enough to bestow from those later years even if he had taken no part in the first days of trial.

Driving along the Delaware in 1790, Stevens unexpectedly came in sight of a little steamboat that Fitch had built, and which was then doing regular passenger service under a printed schedule between Philadelphia and Bordentown. The next year he was engaged in building a boat for himself. In 1796 he was an interested witness of the success made on the Collect Pond. But instead of following paths that had been beaten by others, Stevens branched off in new ways and achieved new successes. For thirteen years he worked on his own lines, and in 1804, after spending more than $20,000, produced a twin-screw propeller which could sail at the rate of four miles an hour when going against the tide, and nearly eight miles an hour when going with it. In 1890 the engine of this prototype of all the great ocean steamers before the coming of the turbine, was placed in a new hull, and still did its credited service. It may now be seen, with the original tubular boiler, the first in the world, at the Smithsonian Institution, in Washington.

To tell of the introduction of the "wave-lines" and the "feathering wheel," the "hog-frame," the "cut-off," and the many other improvements that came from Stevens and are now in use, would carry us away beyond the days of the *Clermont* and outrun our space. We must get back to the claims of John Fitch.

John Fitch was born in Windsor, Conn., in 1743. In a manuscript sketch of his life willed by him to the Franklin Institute, of Philadelphia, Pa., with the condition that it should not be read till thirty years after his death, he says of himself:

"The house I was born in was upon the line between Hartford and Windsor. (Now known as the Old Road.—Ed.) It was said I was born in Windsor, but from the singularity of my make, shape, disposition and

fortune in the world, I am inclined to believe that it was the design of Heaven that I should be born on the very line and not in any township whatever, yet I am happy that it did not happen between two States, that I can at least say I was born somewhere."

Further on he gives us pen sketches of his father, who is seen in not too enviable a light, and introduces two brothers, one of whom is a tyrant, and two sisters, to one of whom Fitch seemed to have been fondly attached. There is a story of hardship and privation up to the time that he marries Miss Lucy Roberts, of Simsbury, by whom two children were born to him, Lucy, who became Mrs. James Kilbourn, and Shaler, who married and settled in Ohio, not far from his sister. Fitch's married life seems to have been no very great improvement over the life he had formerly lived at home. The senior Fitch had such a poor apology for a religion that the son had early turned toward skepticism, and now, to add to the unpleasantness of his home, his wife had taken up with the teachings of the Methodists, a sect then everywhere spoken against, and had "joined the church." This was the last straw, and Fitch left his home and wandered down into New Jersey, where he hung out his shingle as a watchmaker. At the outbreak of the Revolution he took up the manufacture of guns for the American troops, which exposed his property to destruction by the British when they entered Trenton in December, 1776.

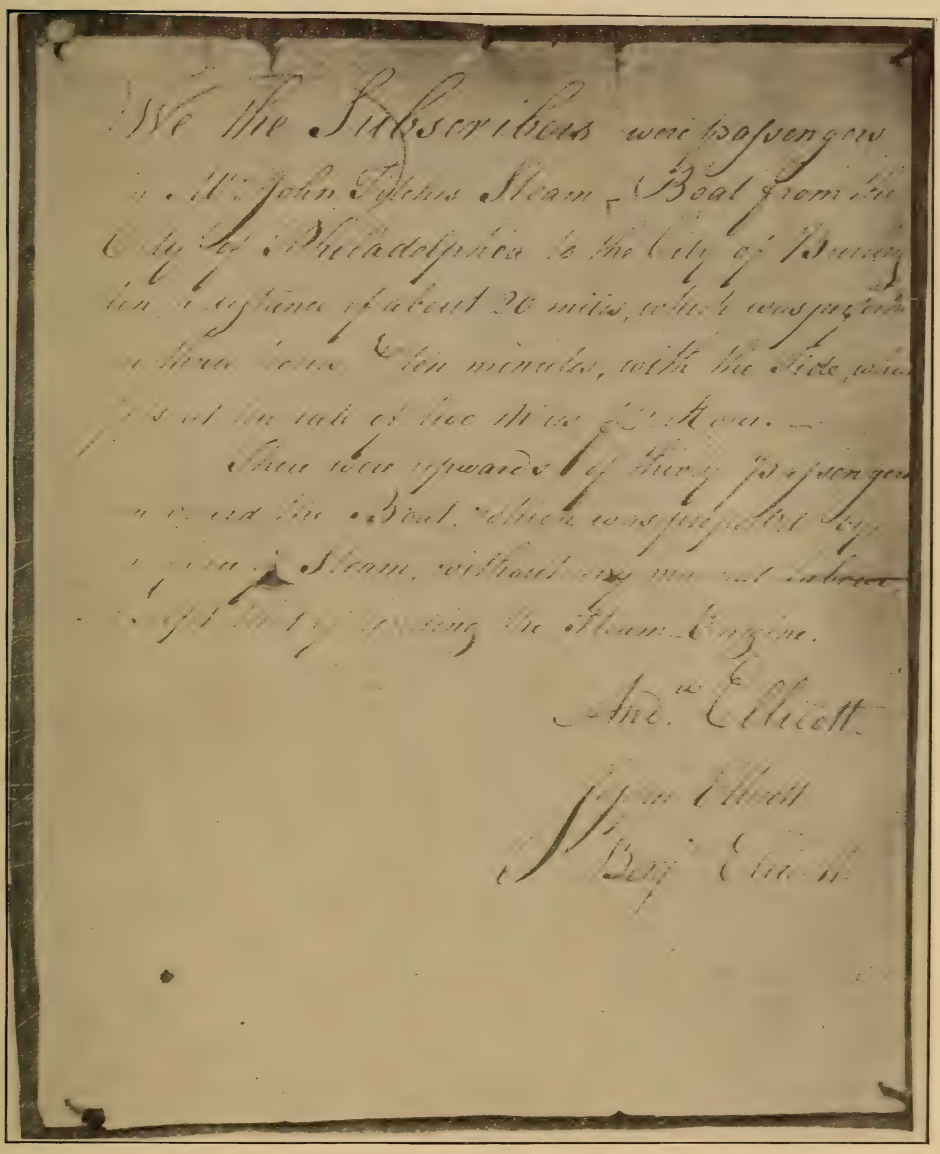
After the destruction of his home and business Fitch joined the New Jersey troops and served through the entire war (being commissioned a Lieutenant), suffering without complaint all the rigors of Valley Forge and the later campaigns. At the close of the war he went into Bucks County, Pennsylvania, where he opened up a shop as a silversmith. It was while here that he first thought of a steamboat. Speaking of those days, Fitch says, in his manuscript:

"In the month of April, 1785, I was so unfortunate as to have an idea that a carriage might be carried by the force of steam along the roads. I pursued the idea for about one week and gave it over as impracticable, or, in other words, turned my thoughts to vessels. From that time I have pursued the idea to this day with unremitted assiduity, yet do I frankly confess that it has been the most imprudent scheme that I was ever engaged in."

Up till this time Fitch had never heard of a steam engine, as he writes:

"What I am now to inform you is not to my credit, but, as long as it is the truth, I will insert it, viz., that I did not know there was a steam engine on earth when I first proposed to gain force by steam. * * * A short time after drawing my first draught for a boat, I was amazingly chagrined to find, at Parson Irwin's, in Bucks County, Pennsylvania, a drawing of a steam engine, but it had the effect to establish me in my other principles, as my doubts lay at that time in the engine only."

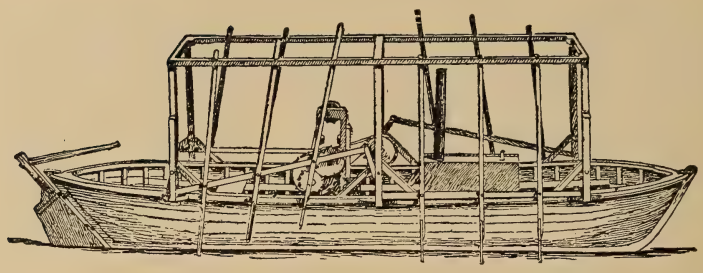
The first model was built in Cobe Stout's log shop and tried on a small stream that ran through Joseph Longstreth's meadow, about a mile and a half from Davisville, in Southampton County. The boiler was made of an iron kettle, the machinery was of brass, and the paddle-wheels—thrown over the sides—were of wood, made by Boilleau. In all, Fitch tried seven different schemes for propelling boats, building complete models of four before he decided upon the scheme shown in his drawings for the American Philosophical Society, of Philadelphia. After experimenting with the endless chain, the screw propeller, paddle-wheels at the sides, and a stern paddle-wheel, Fitch, in 1785, built a model of his boat fitted with the suspended oar-shaped paddles invented by Harry Voight, and presented it to the Society. At the same time, he



TESTIMONIAL SIGNED BY PASSENGERS ON FITCH'S STEAMBOAT ON THE DELAWARE, 1788

wrote to Benjamin Franklin, expressing his belief in the practicability of using steam for navigating the seas.* The next year Fitch obtained from Pennsylvania and some of the adjacent States the sole and exclusive right to navigate the waters therein for vessels propelled by steam. At this time he was experimenting with a skiff, in which he had rigged an engine having but a 3-inch cylinder attached to a small propeller. At first there was nothing but failure, but with a new arrangement of the propelling apparatus, and a larger engine, Fitch finally produced the boat in which, on July 27, 1786, he gave to the world its first successful demonstration of a steamboat.

* Life and writings of Franklin, Vol. 10.



FITCH'S BOAT WITH VOIGHT'S OAR PADDLES, 1785

During the next year he built a second boat, 45 feet long and 12 feet wide, with a correspondingly heavier engine, in which he made a trial trip on the Delaware River on August 22, 1787, which was witnessed by all the members of the Convention then in session at Philadelphia for framing the Federal Constitution. With this demonstration every one seemed satisfied except the inventor himself. Attainment only fired his ambition, and he at once began to plan for larger things.

By the sale of maps of the Northwest Territory, made from his own surveys and engraved in the rude shop of Cobe Stout, where they were printed upon a cider press, $800 was made available for a new boat.

On the trial trip of the new boat everything worked perfectly, and a run was made on October 12, 1788, from Philadelphia to Burlington—a distance of twenty miles. The cost of the second boat, which gave warrant for the third and larger, has recently come to light in the effects of "Brooke and Wilson," shipbuilders, Kensington, Philadelphia, in which there is a ledger entry that reads as follows:

JOHN FITCH
1786—To Brooke and Wilson, Dr.

		£ s. d.
Nov. 23.	To building a steamboat 45 ft., @ 207	45- 1- 0
"	A coat of stuff	1-10- 0
"	6 pieces of timber, @ 2s. 6p. piece	0-15- 0
"	13½ days' work, @ 5s. day	3- 7- 6
		50-12- 6
	155 ft. of board, @ 2d. ft	1- 5-10
		51-18- 4
	Less	16- 8
		51- 1- 8

Some of the other bills relating to this first boat have recently come to light. Among them are the following, printed here for the first time on pages 289 and 291.

It had been demonstrated that a steamboat was practical, and a regular line was announced between Philadelphia, Burlington, Bristol, Bordentown and Trenton. The following card was printed in the press of the day:

The Steam-Boat

IS now ready to take Paſſengers, and is intended to ſet off from Arch ſtreet Ferry in Philadelphia every *Monday*, *Wedneſday* and *Friday*, for *Burlington*, *Briſtol*, *Bordentown* and *Trenton*, to return on *Tueſdays*, *Thurſdays* and *Saturdays*—Price for Paſſengers, 2/6 to Burlington and Briſtol, 3/9 to Bordentown, 5/. to Trenton. June 14. tu.th ſtf

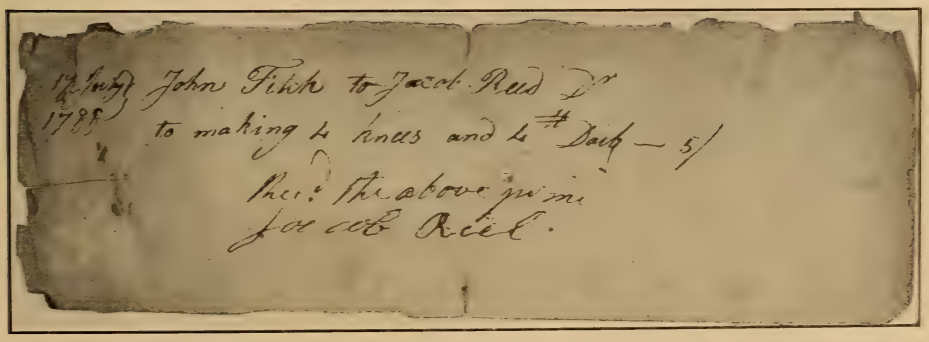
ADVERTISEMENT OF FITCH'S STEAMBOAT ON THE DELAWARE

Hundreds of passengers were carried, tons and tons of freight were transported, thousands of miles were sailed, and then the story closed. Why? Perhaps it was because the new, larger boat that the company had undertaken to build for a New Orleans route was carried by a storm over on to an island of mud and wrecked, badly crippling the finances of the men interested in the enterprise, or there may be an explanation in the level stretches of perfect roadway that lay along the shores of the Delaware, making it possible for fast horses to drag light canal boats at a speed not to be exceeded by the engines that could then be hammered out. But the fact remains that it

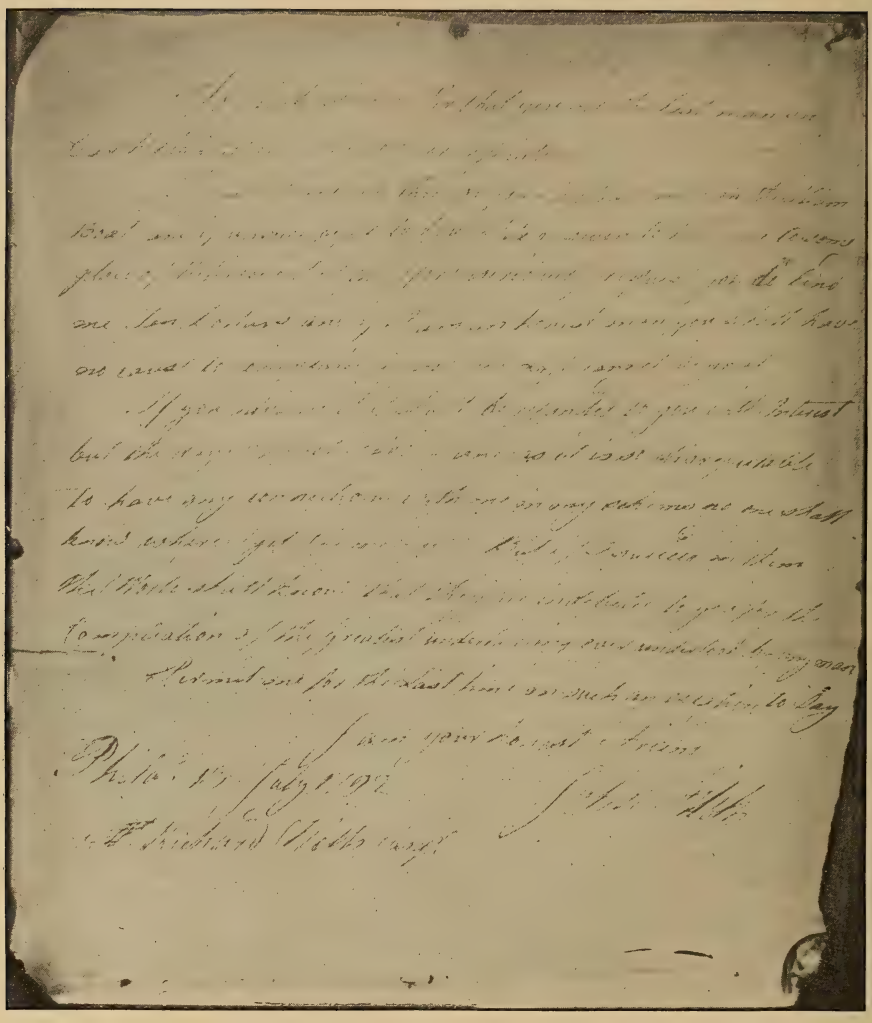
FITCH'S STEAMBOATS. FROM CONTEMPORARY PRINTS

was one of these early boats seen on the Delaware that first set John Stevens thinking about steamboats for the Hudson, and if that boat had first been launched on the river whose banks rise so precipitously on either side in such rugged rockiness as to make travelling by stage coach one of the most dreaded of experiences, no break would have come into the records that bind together two centuries. As it was, if Fitch's boat had been brought over to the Hudson and started for Albany on the morning that Fulton set out with the *Clermont*, it would have reached Albany by the time its more famous rival had come opposite the estate from which it had received its name, outsailing the larger boat by fifty-two miles in a distance of one hundred and fifty.

After the failure in Philadelphia, Fitch went to England and from thence he went to France, where he succeeded in interesting Louis XVI. in his projects so far as to receive from him the patent, bearing the date of November 21, 1791, which may now be seen by the side of a model of his first boat in the Smithsonian Institution, at Washington. However, there was no financial response to his appeal, and Fitch, tired and discouraged, worked his way back as a deck-hand on a vessel coming to America, and went to the house of relatives for a rest. Here he perfected plans for another boat and started off for New York, where he built and sailed two differently propelled steam-yawls in the presence of witnesses. Livingston, Stevens, and Roosevelt all sailed with him around the Collect Pond, where the Tombs Prison now stands, and at

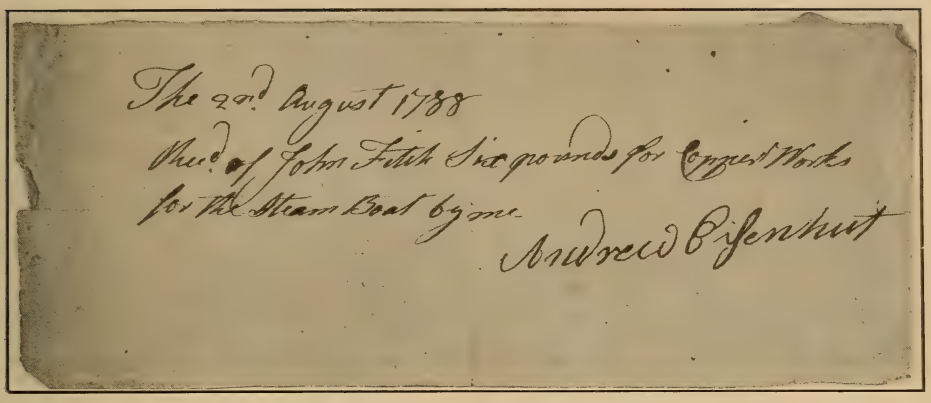


BILL FOR CONSTRUCTION WORK ON FITCH'S STEAMBOAT 1788



LETTER OF JOHN FITCH ASKING FOR AID IN HIS PLANS FOR STEAM NAVIGATION, JULY, 1792

once began experimenting on doing what this friendless Yankee had demonstrated could be done. No one would finance the scheme. There was no friend at court to push the project along, and John Fitch, sick in body as in heart, went off to visit with his old friends in Pennsylvania. Here he met with a message from his wife, who had come into the estate of her father, urging him to return to her home, and assuring him that he should be maintained as a gentleman for the rest of his days; but, proud as he was stubborn, Fitch refused to listen to the arguments of his brother-in-law, Burnham, who brought the message, or the pleadings of his friends, and turned off again toward Kentucky, where he had considerable "government land." He made his way to a little interior town, where he found shelter in the inn of Alexander McCown (not McCord, as generally written), and here, on the morning of July 1, 1798, after an illness of several weeks, he died. Henry Weller made a coffin and, with Alexander McCown and William McQouwn, buried him in the

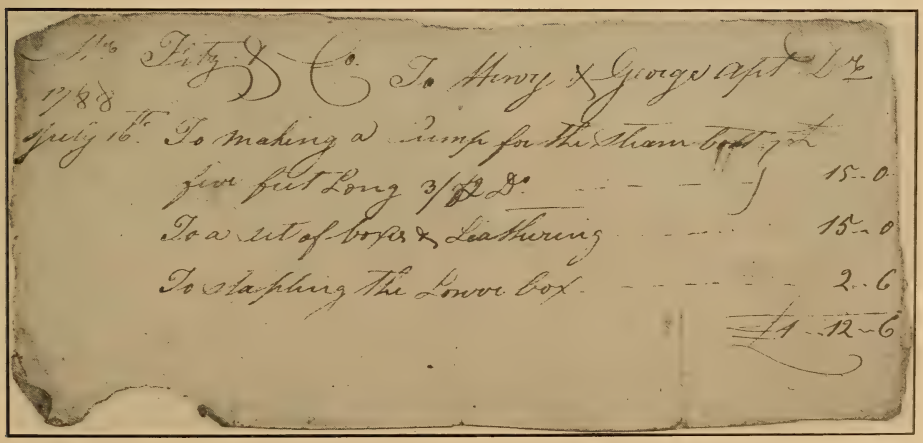


BILL FOR COPPERSMITH WORK ON FITCH'S STEAMBOAT, 1788

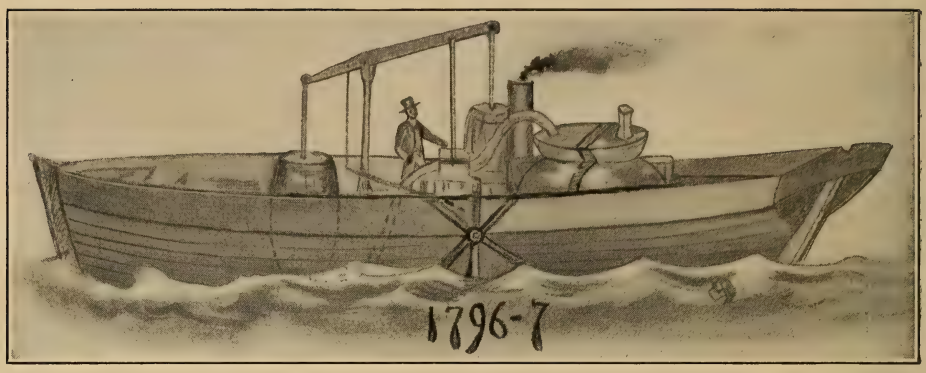
town burying-ground near a pond of water upon which he had sailed his last steamboat—a small side-wheeler built to demonstrate to his friends that what he had said about this achievement was not mere talk, like the telling of a dream. For years his grave was unmarked, but in 1854 a son of Alexander McCown, who had been shown by his father the exact spot where the body of John Fitch lay hidden, set up two stubby pieces of stone from a near-by grave, and these two grass-entangled bits of marble are all that keeps from oblivion the last resting place of the man who first saw and made others see the possibilities of a steamboat.

Recently, among the papers of Dr. William Thornton, who was the first "Commissioner of Patents" in the newly formed government, and a believer in Fitch's claims and abilities, there have been found copies of the will drawn up in Philadelphia. A subsequent will, made in Bardstown, Ky., where Fitch died, makes no mention of these earlier documents, in which the peculiarities of the man are so fully embodied. In the first will we read:

> O Lord, my God, I beseech Thee now to enable me to make this my last will in a rational manner and corformable to the laws of Nature, and that it may not be esteemed in any court of Justice as coming from Insanity.
>
> My will and pleasure is that I should be buried under ground or sunk with weights


Mr. Fitch & Co. To Henry & George Wyatt Dr.
1788
July 16th To making a Pump for the Steam Boat 9 ft
five feet Long 3/12 8d ---- 15-0
To a set of boxes & Leathering ---- 15-0
To Stapling the Lower Box ---- 2-6
£1-12-6

BILL FOR PUMP ON FITCH'S STEAMBOAT, 1788



FITCH'S BOAT ON THE COLLECT POND, NEW YORK

to the Bottom of some water that I do not become more obnoxious to the living than I now am, but if buried that I may be layed on some public highway or place of the greatest resort of the living—such as State House Yard—Gray's Garden or some public House that could hear the Song of the Brown Jug on the first day of February every year. I request that my life may be a lesson of caution to the living, but beg that I may not be buried in or near any Christian burying ground.

But as to my burial, my penury forbids any extravagance. I give two Dollars for my funeral expense and no more. One dollar I bequeath to the man who wheals me to the place of enternment, the other who shall dig a hole to lay me in and cover me up. I also give an Indian Blanket in the hands of Mrs. Leavering to tie my body up in instead of a coffin.

All my estate in New England, both real and personal, I give to my Two children to be equally divided between them.

And as I have lodged seven or eight pounds with the Mason's funds I trust that they will have generosity enough to give every one present a good Drink so as to make them feel glad that they are alive.

In another will Fitch comes back to the same bequests, but in this will he refers to some manuscripts left with the Masons, which are to be sold and the income to be placed on interest, "which shall be annually paid on the first of February to the person who shall go to my grave on s^d day, at 4 o'clock in the afternoon, in the presence of several witnesses, and sing of the Brown Jug, and that he is gone like a true-hearted fellow, which shall be shared by him in equal proportions to all present either in liquor or money, as the singer shall direct."

Straight as an arrow, six feet two inches tall; thin and spare, face slim and complexion tawney; hair jet black, eyes dark and peculiarly piercing; temper sensitive and quick and stubborn—such was John Fitch. His ancestry, for he had a most respectable ancestry with a vellum of pedigree and a coat of arms, were originally Saxon and emigrated to Essex, England, from whence they came to Windsor, where the great-grandfather purchased one-half the original settlement, leaving it at his death to three sons—Joseph, Nathaniel and Samuel. From the loins of Joseph sprung John, who was the father of the John to whom the boiling over of a tea-kettle suggested the latent force of steam.

GASOLINE ENGINES FOR AUTOMOBILES

A COMPARISON OF THE FOUR-CYLINDER AND SIX-CYLINDER VERTICAL TYPES

By David Fergusson

The automobile engine represents one of the most interesting forms of the internal-combustion motor, not only because of its rapid and extensive development, but also because it represents the maximum development of power with a minimum of weight. M. Boyer has discussed, elsewhere in this issue, the relative progress of the four-cylinder and the six-cylinder types in France, and Mr. Fergusson here makes a critical comparison of these same classes in the United States. Each type doubltess has its place in the automobile industry, and such discussions will aid in rendering those places more readily and definitely determined.—THE EDITOR.

THE advantages and disadvantages of each of the above types of engines have been discussed by the automobile press at considerable length during the past twelve months. However many points those discussing the above were at conflict with, they were unanimously agreed that the six-cylinder engine was an altogether better balanced mechanism than the four. On the other hand, there was a doubt as to whether the six-cylinder engine did not weigh more than the four-cylinder of the same horse-power. There was no disputing the fact that the six-cylinder engine was more costly to make and more complicated, and that it took up more space in regard to length.

In the following article it is the writer's object to present a few facts that have been gleaned from the actual construction of the two types of engines of almost the same horse-power installed in a chassis carrying the same body constructed to carry seven passengers. In both these designs the same factors of safety were allowed, and the same features of design and relative proportions adopted.

In the case of the four-cylinder engine, the cylinders were 5 inches bore $\times$ $5\frac{1}{2}$ inches stroke, compression 70 pounds per square inch. This gives an estimated brake-horse-power at 1,000 feet per minute piston speed, taking the mean effective pressure as 85 pounds per square inch, and an efficiency of 80 per cent., as follows:

$$\frac{85 \times 1{,}000 \times 19.63 \times 80}{33{,}000 \times 100} =$$

40.4 brake-horse-power.

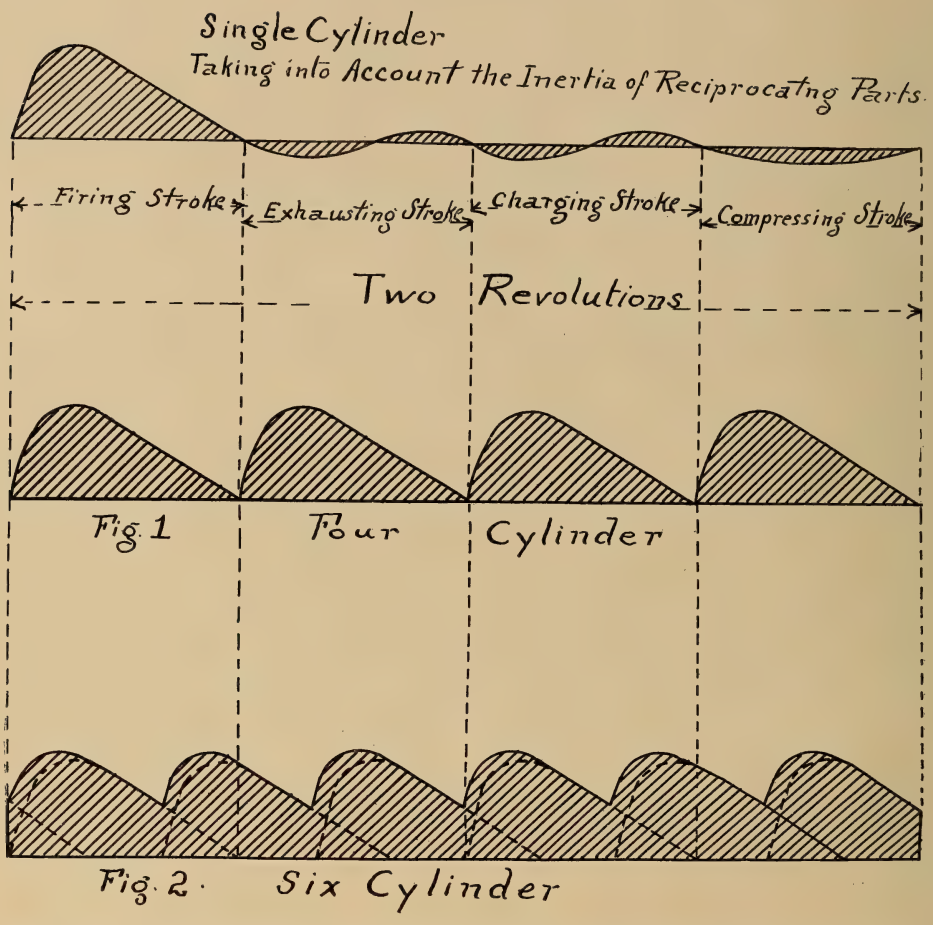
In the case of the six-cylinder engine the cylinders were $4\frac{1}{4}$ inches bore by $4\frac{3}{4}$ inches stroke. With 70 pounds compression, the estimated brake-horse-power at 1,000 feet per minute piston speed is:

$$\frac{85 \times 14.18 \times 1{,}000 \times 80}{33{,}000 \times 100} =$$

29.2 brake-horse-power + 50 per cent. = 43.8 brake-horse-power. So that at 1,000 feet per minute piston-speed the six-cylinder engine, though of less piston displacement, having 404 cubic inches against 431 cubic inches, gives 3.4 more power. This is, of course, due to the greater number of revolutions per minute for the same piston speed. At 1,000 feet per minute the four-cylinder engine is running at 1,090 revolutions per minute, and the six-cylinder engine is running at 1262 revolutions per minute.

The six-cylinder engine will be running at 1,161 revolutions when developing 40.4 brake-horse-power. This gives a piston-speed of 919 feet per minute.

The largest single factor in regard to weight is the fly-wheel, and a great



FIGS. 1 AND 2.—DIAGRAM SHOWING THE TANGENTIAL EFFORT ON THE CRANK PINS OF ONE, FOUR AND SIX-CYLINDER ENGINES

saving can be effected in this in the six-cylinder engine over the four.

The estimated weight of the fly-wheel for the four-cylinder engine calculated for a 10 per cent. variation, at a speed of 500 revolutions per minute, gives a weight of 114 pounds for the fly-wheel rim. For the six-cylinder engine for the same speed and variation the weight of the rim need only be 15 pounds.

This illustrates the effect of the greater number of impulses per revolution, and of their overlapping one another, giving an almost uniform torque on the crankshaft in the case of the six-cylinder engine. This is shown in the diagrams, Figs. 1 and 2, which show the tangential pressure on the crank-pins for the four and six-cylinder engines, respectively.

In Fig. 1 it will be seen how the effort on the crank-pins of the four-cylinder engine is at a maximum a little after the commencement of the firing stroke, and that it dies down to nothing at the end, there being no propulsive effort exerted on the crank-shaft at the ends of the stroke. On the other hand, in Fig. 2, the crank-shaft is at no time without a very considerable turning effort being exerted, giving a sustained and continuous torque. In the first case a very heavy fly-wheel is necessary in order to give a turning effort during

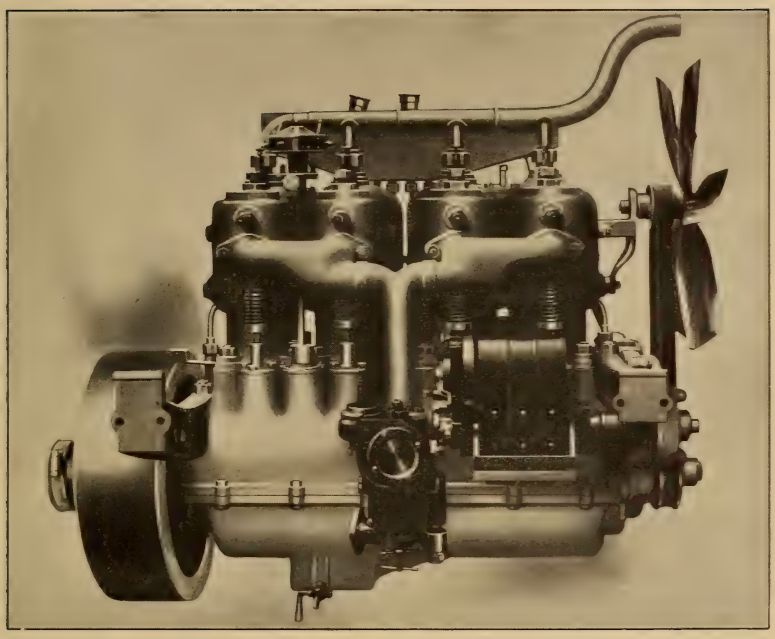


FIG. 3.—GREAT ARROW FOUR-CYLINDER MOTOR, RIGHT-HAND SIDE

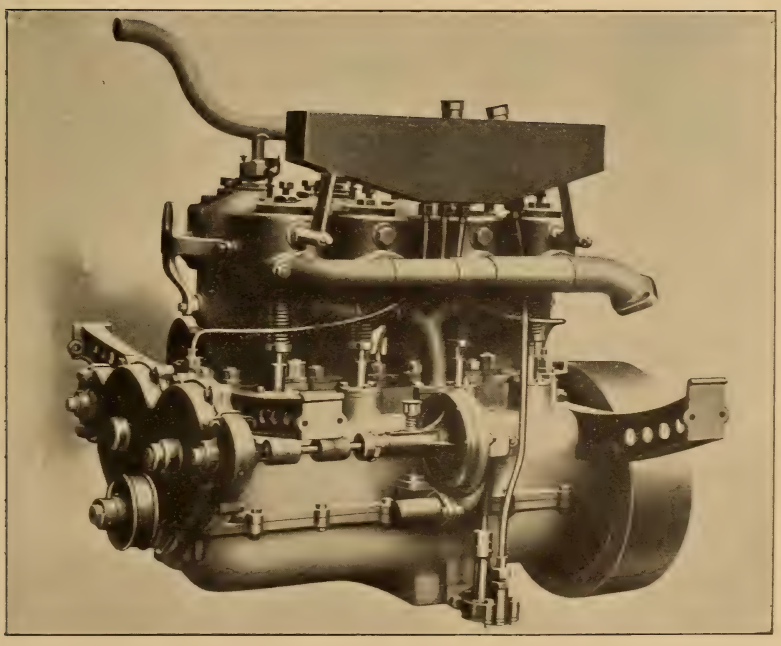


FIG. 4.—GREAT ARROW FOUR-CYLINDER MOTOR, LEFT-HAND SIDE

the non-propulsive parts of the stroke. In the latter case the fly-wheel can almost be done away with, as the propulsive effort does not drop very materially at any part of the stroke.

The following is a list of the principal parts comprising the engines, with their actual weights:

	$5 \times 5\frac{1}{2}$ Four-Cylinder Engine, Pounds	$4\frac{1}{4} \times 4\frac{3}{4}$ Six-Cylinder Engine, Pounds
Crank shaft	47	54½
Cylinders with plugs, but without valves	204	210
Pistons with gudgeon pins and rings	35	30
Connecting rods with bushes	26	25½
Crank case with supports, valve gear cover, and oil pan, water pump, magneto gears, shafts and bushes	143½	175
Fly wheel	102½	44½

The actual total weight of the complete four-cylinder engine was 748 pounds, and of the six-cylinder engine, 764 pounds.

These weights include fly-wheel, cone clutch and spring, carbureter and inlet piping, exhaust branch pipe and water branch pipe, water pump and magneto. In this case the six-cylinder engine weighed 16 pounds more than the four. This extra weight is due to the fact that the fly-wheel of the six-cylinder engine was made heavier than theoretically necessary, and the fly-wheel of the four-cylinder engine was not made quite as heavy as theory indicated. However, apart from this, it is quite evident from the above that a six-cylinder engine can be made lighter than a four-cylinder engine of equal horse-power, as in this case the six-cylinder engine develops 3.4 horse-power more than the latter, at 1,000 feet per minute piston-speed.

In regard to the over-all length of the engine, Fig. 5 shows a longitudinal section through this six-cylinder engine as compared with the four-cylinder. The former is 9 inches longer than the latter. In the up-to-date chassis the front axle is placed directly under the radiator. This places the front wheels away forward, and necessitates a long wheel base, but it has the advantage of easier riding and less weight on the front tires, therefore easier steering. In the case of the six-cylinder engine, the front axle can, without any disadvantage, be placed 3 inches behind the radiator and still have no more weight on the front tires than in the case of the four-cylinder engine. This leaves us with 6 inches more room taken up by the six-cylinder engine towards the rear, necessitating a 6-inch longer wheel base to get the same body on the chassis with the same overhang of the body over the rear axle in both cases.

The wheel bases of these two cars were 124 inches and 130 inches, respectively. This gives ample room for two extra seats in the tonneau, thus making a very comfortable seven-passenger car, with an advantage of 6 inches less over-all length in favour of the four-cylinder car.

The total actual weight of the complete car was practically the same, being a trifle less in the case of the six-cylinder, as, although the underframe is heavier, due to its greater length, yet the transmission case, gears, and propeller shaft are lighter, as the torque per revolution of the engine is less in the six than in the four, since in the former the engine is running 1,161 revolutions per minute and in the latter 1,090 revolutions per minute when developing 40.4 horse-power. Both cars are geared to give the same number of revolutions per minute of the rear wheels.

The first noticeable feature in comparing the running on the road of these two machines was the absence of vibration caused by the running of the engine in the case of the six-cylinder engine as against the four either with the vehicle standing and the engine running, or at any speed of the car from its minimum to its maximum. Most people whose experience does not extend beyond the four-cylinder, consider this a beautifully balanced engine, but the vibration is quite noticeable when compared with the six-cylinder machine.

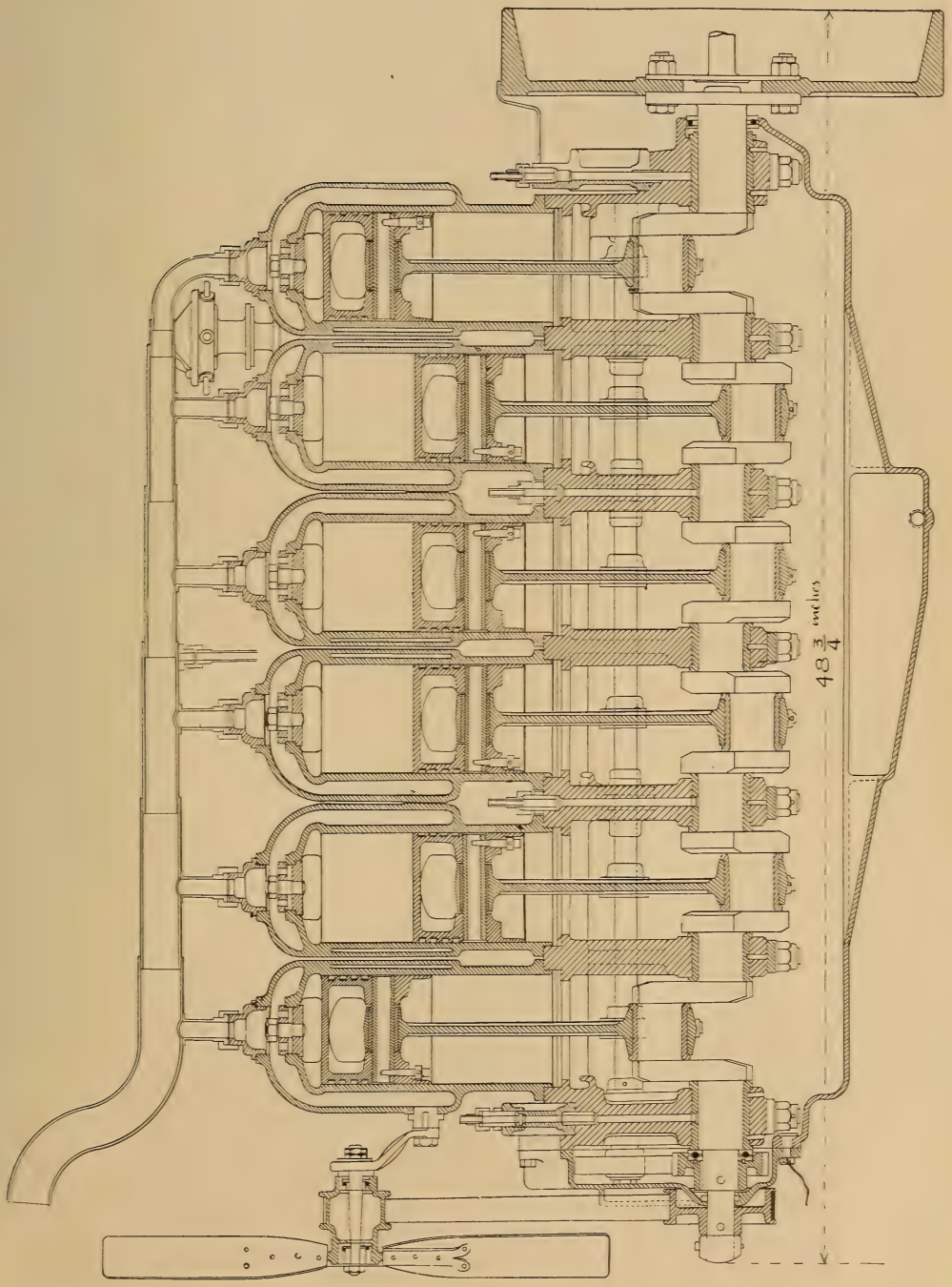


FIG. 5.—LONGITUDINAL SECTION OF GREAT ARROW SIX-CYLINDER AUTOMOBILE MOTOR

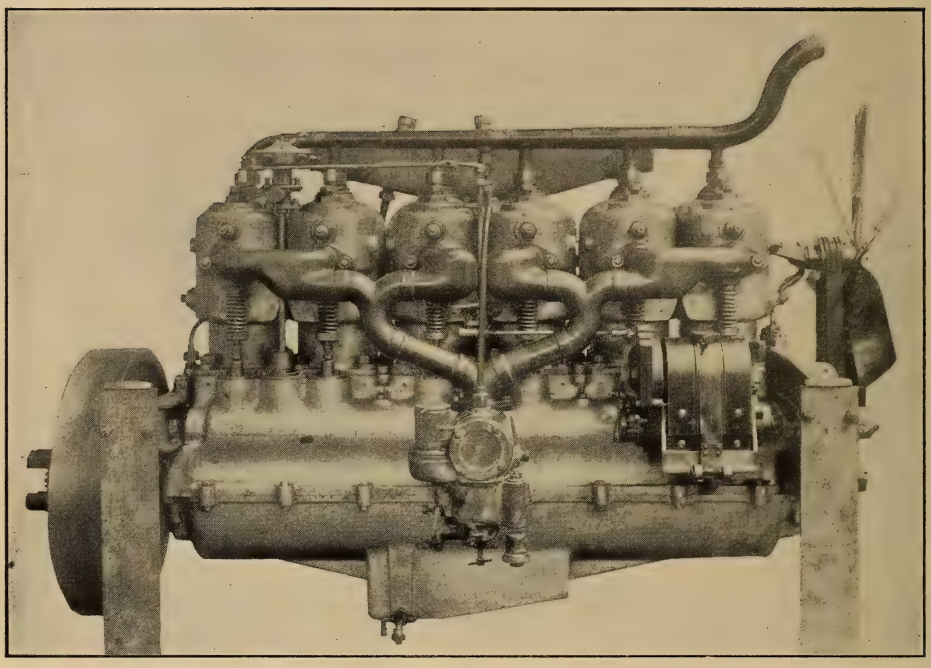


FIG. 6.—SIX-CYLINDER ENGINE OF GREAT ARROW CAR, RIGHT-HAND SIDE

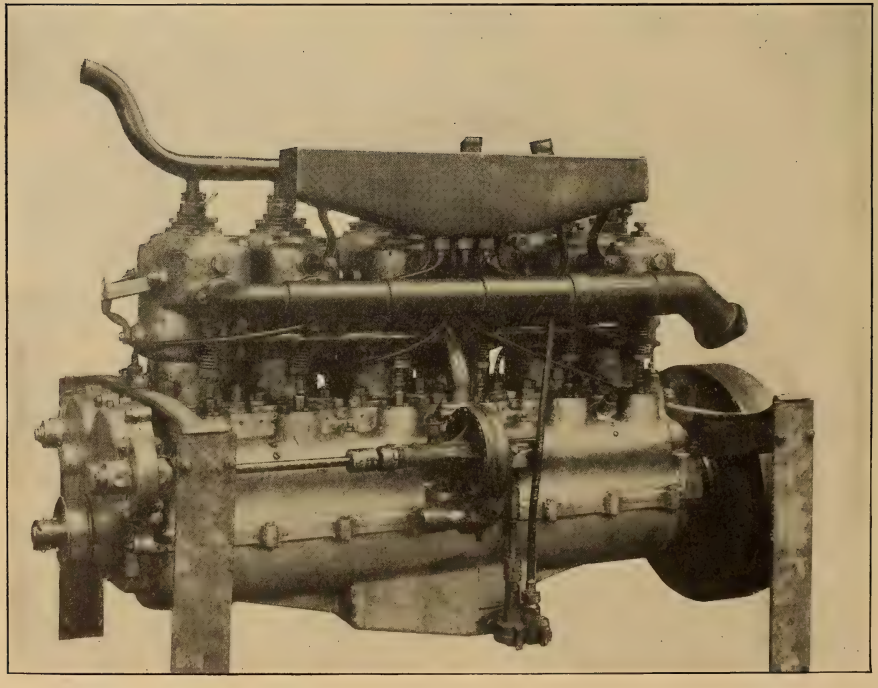


FIG 7.—SIX-CYLINDER ENGINE OF THE GREAT ARROW CAR, LEFT HAND SIDE

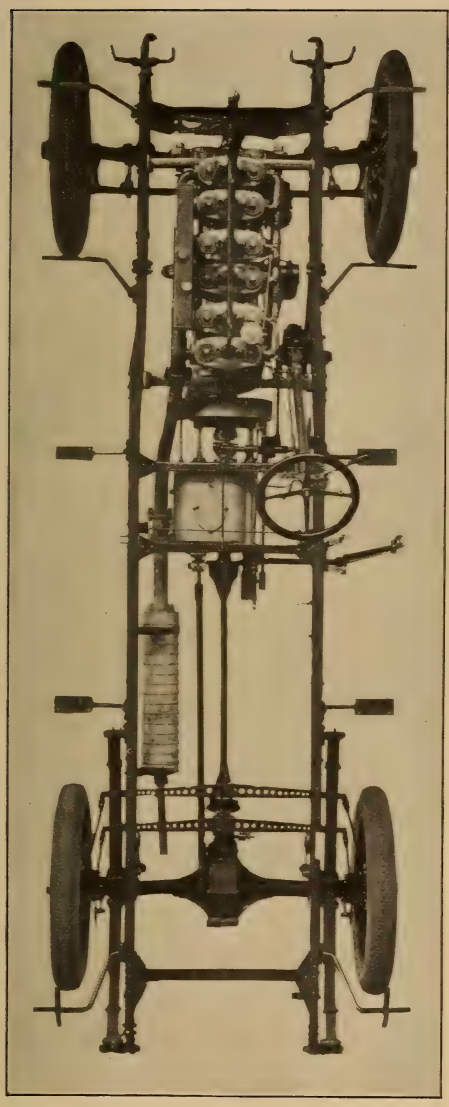


FIG. 8.—GREAT ARROW CAR. PLAN OF CHASSIS FOR SIX-CYLINDER, 60-HORSE-POWER CAR

Every one admires the beautiful running of a car when coasting down hill with the motor stopped and the clutch disconnected. This is the manner in which a six-cylinder car runs all the time. The sensation is delightful, and this feature alone is bound to make the six-cylinder car the most popular of high-class cars.

Second. *Silence.* The six-cylinder car is much quieter than the four, the exhaust due to the rapid sequence of explosions being practically continuous. The engine, being in perfect balance, contributes to this quietness.

Third. *Flexibility,* due to the more constant torque obtained by the constant impetus of continuous explosions, giving an ability to run powerfully and smoothly at any speed from 4 miles an hour to 60.

Fourth. *Ease of Operating,* owing to their being less necessity for changing gears especially in traffic, as the six-cylinder car can be run much slower than the four when on the high gear.

The above features show a very marked superiority in favour of the six-cylinder car. There are other points that are not so obvious, and yet they may be claimed as advantages—longer life and less liability of breakages of the transmission mechanism, due to there being less shock; less wear and tear on rear tires, owing to more even propelling impulses.

The conclusions of the writer are that the above advantages are so great to those who desire the best that the extra cost and complication of the six-cylinder engine are not to be considered. It is a recognized fact that engine troubles are to-day very rare in well-made automobiles, and to have 50 per cent. more cylinders, pistons, valves, etc., is not going to make these troubles any more frequent. The extra cost of these parts is not of any moment to the manufacturer, if he can get a higher price for his car, and this will willingly be given by those who desire and can afford the best that the automobile manufacturers can produce. It might be asked that if six cylinders are better than four, would not a greater number of cylinders give still better results? The answer to this is that six is the least number of cylinders by which a perfect balance can be obtained and, having attained this perfection of running, it is needless to multiply further these parts.

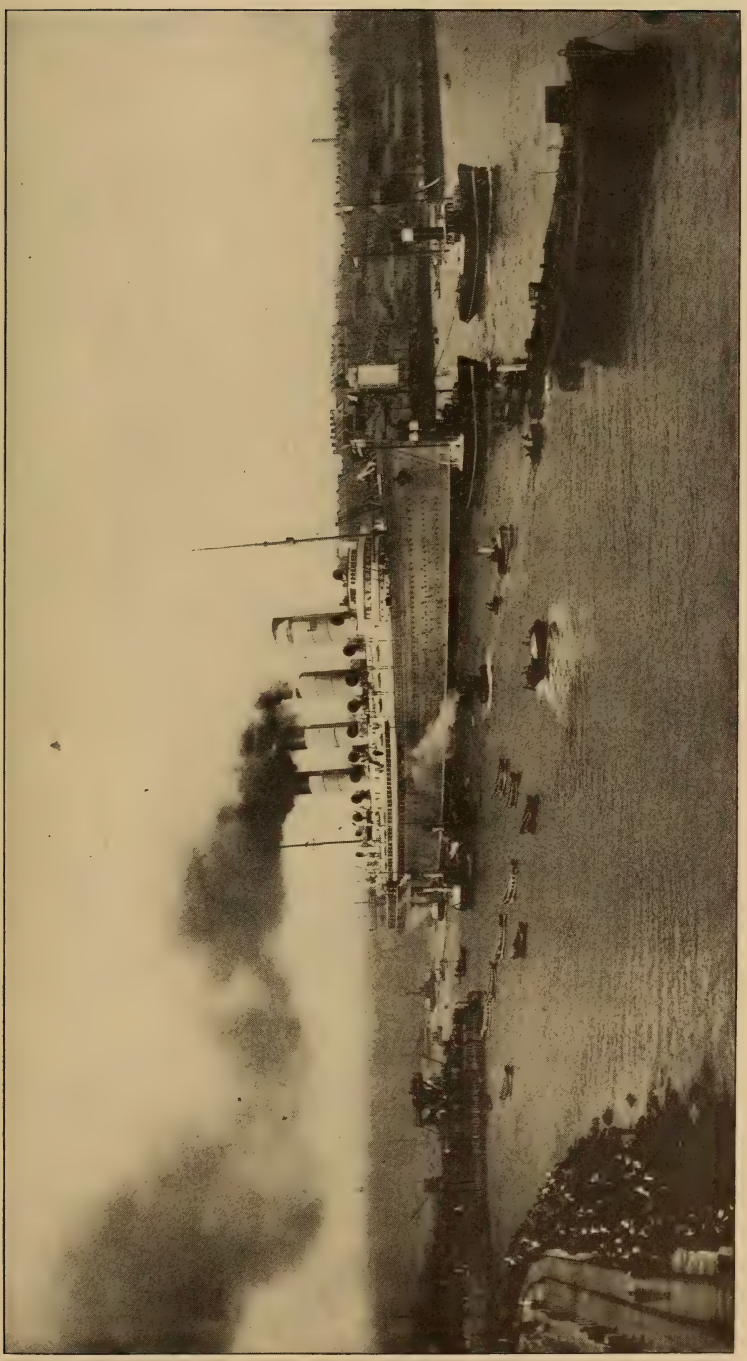
Current Topics

THE completion of the *Mauretania* marks the actual beginning of the well-considered effort of the Cunard Line to recapture the speed record of the Atlantic from the German steamship lines. Already the *Lusitania* has beaten the record of the *Kaiser Wilhelm II.* and the *Deutschland,* and her run of 618 miles in 24 hours has well surpassed the 601 miles made by the Hamburg-American liner, only to be exceeded, in turn, by the record of 624 miles by the *Mauretania* on her first westward trip through gales, heavy seas, and heavier fog.

In carrying out the plans for the construction of the two great Cunarders it was decided to build one, the *Lusitania,* on the Clyde, at the yard of Messrs. John Brown & Co., Ltd., and the other, the *Mauretania,* on the Tyne, at the establishment of Messrs. Swan, Hunter & Wigham Richardson, Ltd.

The conditions laid down in the agreement entered into in 1903 between the British Government and the Cunard Company required the construction of two steamships "capable of maintaining during a voyage across the Atlantic a minimum average speed of from 24 to 25 knots (say, 27 to 29 statute miles) per hour in moderate weather." This stipulation, coupled with the large amount of passenger accommodation aimed at, the stringent requirements of the British Admiralty, and the determination of the owners to make the vessels much stronger than any other fast Atlantic vessels afloat and to introduce every known contrivance for the safety and comfort of the passengers, compelled the designers to adopt unprecedented dimensions.

In general, the speed of a vessel depends upon certain known relations between the displacement and form of the hull and the power of the propelling machinery. With the dimensions decided for the new Cunarders, however, the limits of existing precedents were so far exceeded that precise data were lacking. It became apparent, therefore, that experimental investigations were necessary, and the whole subject was



THE MAURETANIA LEAVING THE TYNE

made the occasion of careful study.

Models of the proposed steamships were designed by Swan, Hunter & Wigham Richardson, John Brown & Co. and Vickers, Sons & Maxim, and tested by Mr. R. E. Froude in the Admiralty experimental tank at Haslar, and further models of increased breadth and finer lines were made and tested under the direction of Sir Philip Watts, Director of Naval Construction.

As a further instance of the care and patient research which have characterized those responsible for the design and construction of the great liner, the model experiments carried out by Swan, Hunter & Wigham Richardson may be quoted. An exact model of the vessel, 47½ feet long, and provided with electrically-driven propelling machinery, was built, and a series of experiments commenced, in order to arrive at the most suitable form of the after lines of the ship, and the number, position and design of propellers likely to give the most satisfactory results. These investigations, which extended over about nine months, were the most elaborate of their kind ever carried out, and the data derived was of great value to the builders.

The form of hull and the necessary powering having thus been determined experimentally, the method of generating the power had to be decided. The limits of the reciprocating system appear to have been almost reached in the latest trans-Atlantic liners, especially in connection with the transmission of the power from the engines to the propellers through the shafting. By the use of the steam turbine higher rotative speeds became possible, while the distribution of the propulsive effort among four shafts and propellers enabled the computed power of 65,000 to 70,000 horse-power to be handled within constructive limitations. Thus the propelling machinery of the *Mauretania* and her sister ship becomes the crowning tribute to the inventive genius and indomitable perseverance of the Hon. Charles Algernon Parsons, the man to whom, above all others, the success of the steam turbine is due.

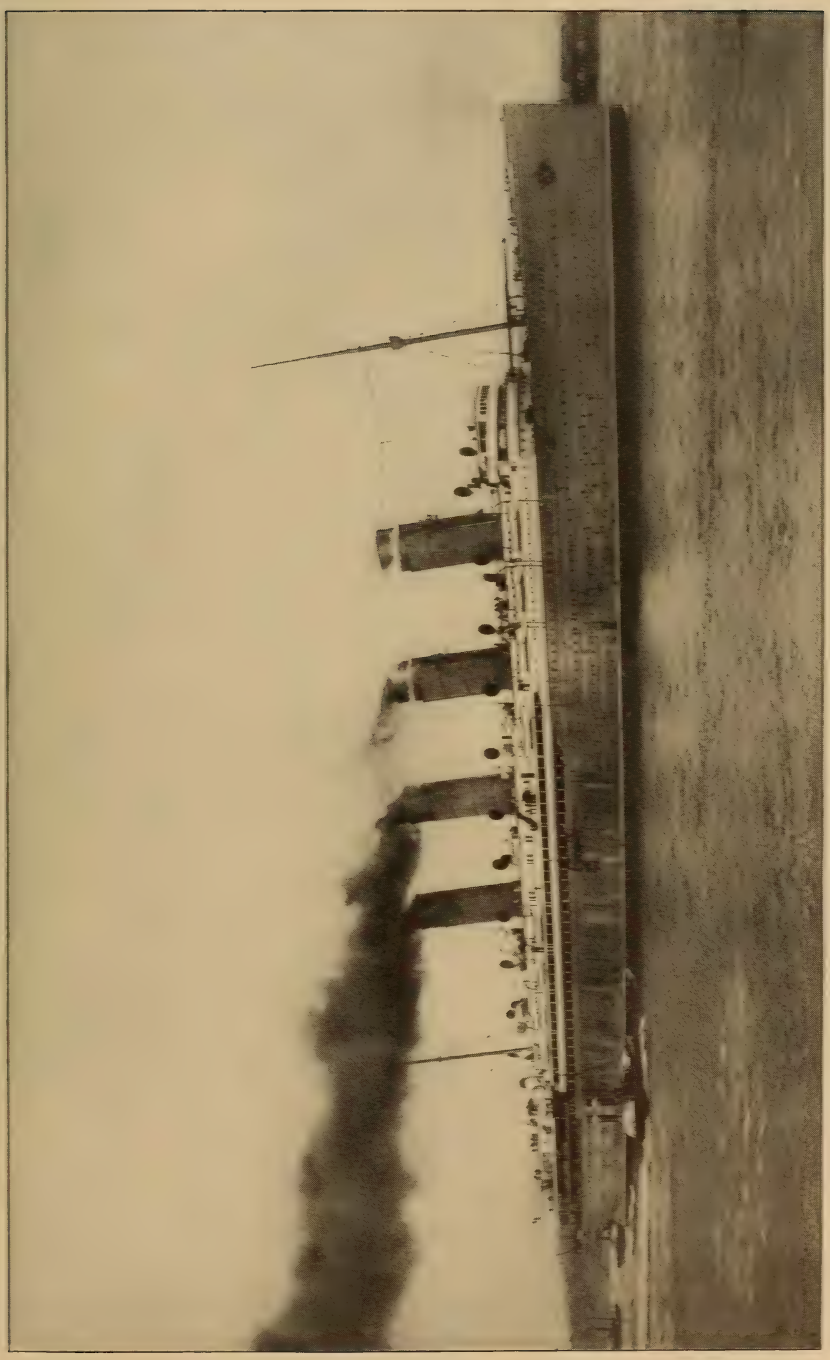
The following are the leading dimensions of the *Mauretania:*

Length over all	790 feet.
Length between perpendiculars	760 feet.
Breadth, extreme	88 feet.
Depth, moulded	60 feet 6 inches.
Gross tonnage	32,000 tons.
Maximum draught	37 feet 6 inches.
Registered displacement	44,640 tons.

Brunel's wonderful creation, the *Great Eastern,* the standard by which the public endeavour to obtain an idea of the size of our greatest modern steamships, was 95 feet shorter, 5 feet less in breadth, and 3 feet less in depth than the *Mauretania,* while the gross tonnage was 7,640 short of the Cunarder's.

The two fastest German liners now crossing the Atlantic are the *Kaiser Wilhelm II.* and the *Deutschland.* The gross tonnage of the former is 12,000 less, and that of the latter 15,498 less than the tonnage of the *Mauretania.* The new Cunarder and her sister, the *Lusitania,* are the largest vessels in the world and the fastest merchant steamers afloat. The *Mauretania,* however, is actually a little larger than the other vessel, being greater in depth by 5 or 6 inches. To the uninitiated this increased depth appears insignificant, but extending the vessel's total length of 790 feet, it represents an addition of about 300 tons to the gross tonnage when compared with the *Lusitania.*

The *Mauretania's* turbines and boilers, with coal bunkers, occupy a total length of from 400 to 450 feet amidships, with a depth from the main deck to the double bottom. The coal bunkers along the sides of the ship are so arranged that they will afford protection to the most vital and important parts of the vessel if used as a scout or cruiser in time of war. For the same reason the principal machinery is placed below the water-line of the ship. Two high-pressure and two low-pressure turbines are provided, each having a



THE MAURETANIA—THE LARGEST SHIP IN THE WORLD

separate shaft and each driving one propeller. The total power developed is about 65,000 to 70,000 I. H. P., so that each of the *Mauretania's* four propellers exerts nearly twenty-four times the power of the paddle steamer *Britannia,* the first Cunard steamer. Throughout, the machinery of the new vessel (including the steering gear and engines) has, as far as possible, been duplicated, so that in the event of accident she can always be worked by one set of engines. When the engines are running, the rotating mass in the engine room weighs 600 tons, and this weight revolves at about 200 revolutions per minute. Some of the larger castings which form the low-pressure turbine casings weigh 38 tons each. The weight of the ingots from which the large drums were forged was 120 tons each. About one and one-half million blades have been fitted in the turbine machinery, and if these blades were placed end to end they would extend a distance of about 110 miles.

Steam is supplied by twenty-three double-ended and two single-ended boilers, having 192 furnaces in all. Air is supplied to the boilers by Howden's system of forced draught, the fans being driven by electric motors.

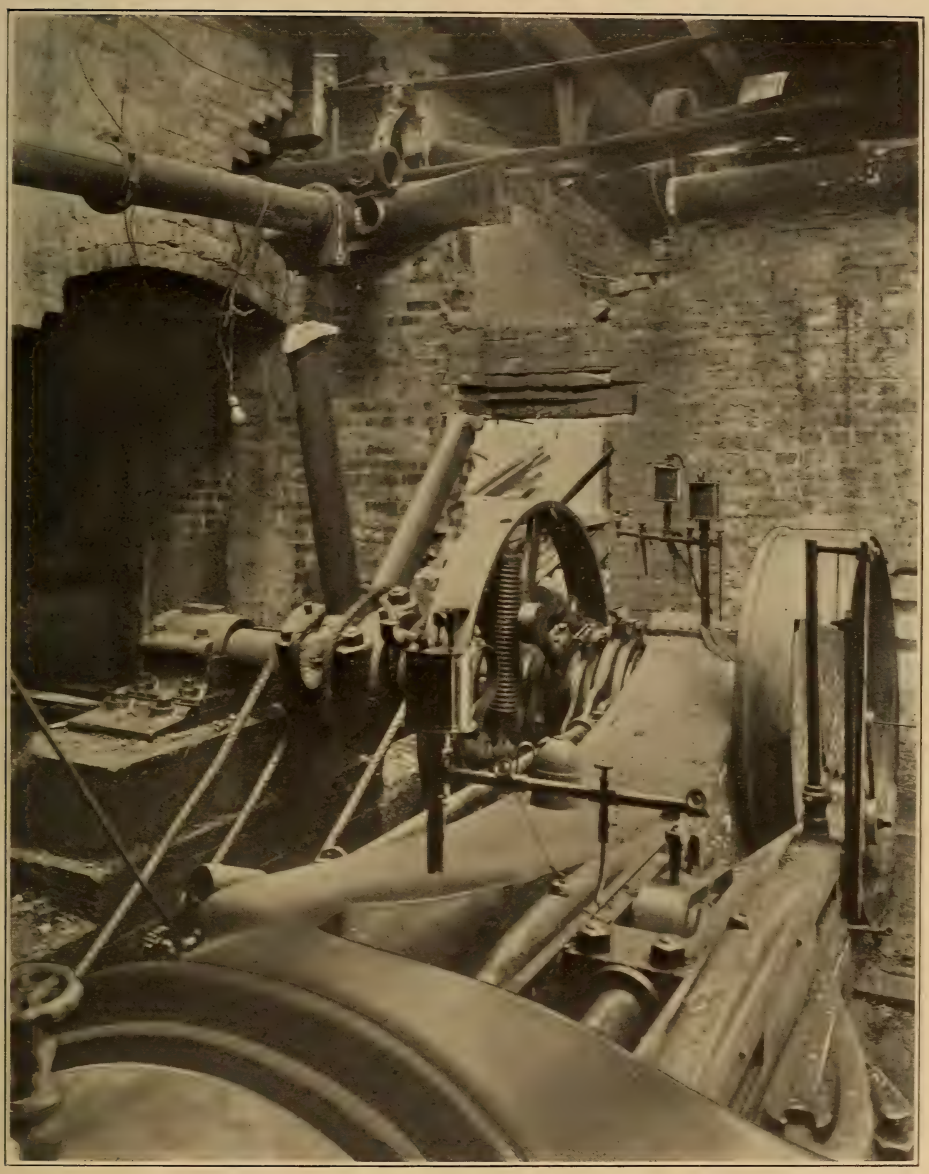
Apart from the great carrying capacity of the new vessels, their speed is certain to be of the greatest commercial value in connection with the improvement of the transatlantic mail service. Ordinarily it has taken about three weeks for the transmittal of a letter across the Atlantic and the receipt of a reply. Until now a letter carried by a vessel leaving England on Saturday was not delivered in New York until it was too late to send a reply on the vessel leaving on the following Saturday. The *Mauretania,* leaving on Saturday, delivers her mails in New York on the following Friday, in ample time for responses to be sent on the vessel leaving on the next day, thus making it possible to receive and answer within two weeks.

IN our August issue there appeared a paper discussing the dangers and losses occurring through the explosion of engine fly-wheels and other rotating parts, when, for any reason, the speed rises so high that the centrifugal force exceeds the strength of the material. There are numerous causes for such runaway disasters, and one of the most frequent is the breakage or slippage of a belt, the main belt of the engine and the governor driving belt being most important in such cases. It has generally been believed that the so-called shaft governor, in its various forms, was much safer than the belt-driven governor, inasmuch as it is positively attached to the shaft, and hence cannot be cut loose by a belt failure. It is important to note, however, that the breakage of the very part which throws the load off of the engine may also cripple the governor or wreck a safety device at the very moment when it should be free to act.

Such a case is shown in the two illustrations here given. In this case, at the plant of the Chicago Coated Board Company, there was a fly-wheel 8½ feet in diameter, grooved for rope drive, the wheel being 18 inches face, with ten grooves for 1¼-inch rope. This wheel broke suddenly, killing one man and producing the wreck so clearly shown by the photographs.

Although it is not always practicable to follow the sequence of events in such a disaster, the condition of the wreck indicates fairly well what occurred. Apparently the driving rope broke, winding around the tension carriage which formed a portion of the rope-transmission system, breaking this carriage and throwing fragments into the engine governor, effectually damaging it and preventing it from acting when the engine, freed from its load, began to race, and unchecked, attained the speed which caused the wheel to burst.

It is the possibility of just such entanglements which renders it most



WRECK FROM FLY-WHEEL EXPLOSION. CHICAGO COATED BOARD CO.

important to exercise every caution in installing safety appliances for protection against explosions of fly-wheels. The safety control may be so placed as to be exposed to the same danger as the rest of the machinery and be wrecked by the very disaster which it was installed to prevent.

It is an old axiom in shop practice that anything in the plane of a rapidly revolving part is liable to be struck by a flying piece, and when, as in the case of the vertical spindle wood planing machine, sometimes called the Daniels planer, the plane of the dangerous revolving piece is horizontal, there is no part of the

CYLINDER END OF ENGINE WRECK. CHICAGO COATED BOARD CO.

floor which is out of its range. In most engine rooms, however, it is possible to place the speed control in such a position that it is fairly well protected against injury from breaking belts or other damage, but such protection is not always considered as fully as it should be.

JAMES DOUGLAS, LL. D.

A BIOGRAPHICAL SKETCH

By Albert R. Ledoux

JAMES DOUGLAS, LL.D., is a native of Canada, although he has resided in the United States since 1875.

The readers of this technical magazine are presumably most interested in the professional achievements of a man, but there can be no adequate understanding of the career of Dr. Douglas without some knowledge of his early life.

His father was one of the most distinguished men of science of Canada, having a very large practice as a physician and surgeon, a man of broad culture and large benevolence, and the founder of the first public institution in the Dominion for the care of the insane.

After two years' study at the University of Edinburgh, which he entered in 1885, and further study, leading to graduation, at Queen's University, Kingston, Ontario, Dr. Douglas returned to Edinburgh, where he took a course in theology, intending to enter the ministry. His early life was largely notable for philanthropy, in the Greek meaning of the word, and dominated by his religious convictions. His taste was distinctly literary; in Edinburgh he carried off a prize in English literature.

After his graduation, father and son travelled extensively together in Europe and in the Orient, visiting Egypt two or three times. They returned with important archæological collections, subsequently donated to the New York Museum of Art. But Dr. Douglas, Sr., had invested heavily in gold and copper mining in Canada. This fact, and the son's early friendship for the late Dr. T. Sterry Hunt, led him gradually away from the inviting paths of strictly religious and literary work into the fields of mining, metallurgy and chemistry. For three years he was professor of chemistry in Quebec. He entered these new fields with the same keen intelligence and honesty of purpose which were always shown in whatver he attempted. His literary training shows itself to-day in his scientific reports, which are distinguished for lucidity and accuracy. In the midst of a busy career he has found time to make frequent contributions to literature and history. He is an authority on many phases of the early history of his native Dominion. Likewise his papers on economic and philosophical subjects have brought him reputation and honors.

It is not possible to give, in this necessarily brief notice, a list of his publications in the literary, historical, religious, philosophical and sociological fields. They will be found in several volumes and in many American, as well as Canadian and British journals, and in the transactions of several societies. His contributions to the history and practice of mining and metallurgy, and particularly his lectures and papers on economic questions, are many and weighty. Among them may be noted:

The Gold Fields of Canada—1863.

The Copper Deposits of Harvey Hill—1870.

Recent Spectroscopic Observations of the Sun—1870.

The Copper Mines of Chili—1872.

The Copper Mines of Lake Superior—1874.

Condition of the Survey for the Canadian Pacific Railway—1874.

Historical and Geographical Features of the Rocky Mountain Railroads.

The Metallurgy of Copper—1883.

The Cupola Smelting of Copper in Arizona—1885.

Copper Production of the United States—1892.

Recent American Methods and Appliances in the Metallurgy of Copper, Lead, Gold and Silver (Cantor Lectures)—1895.

Record of Borings in Sulphur Spring Valley, Arizona—1898.

Treatment of Copper Mattes in Bessemer Converter—1899.

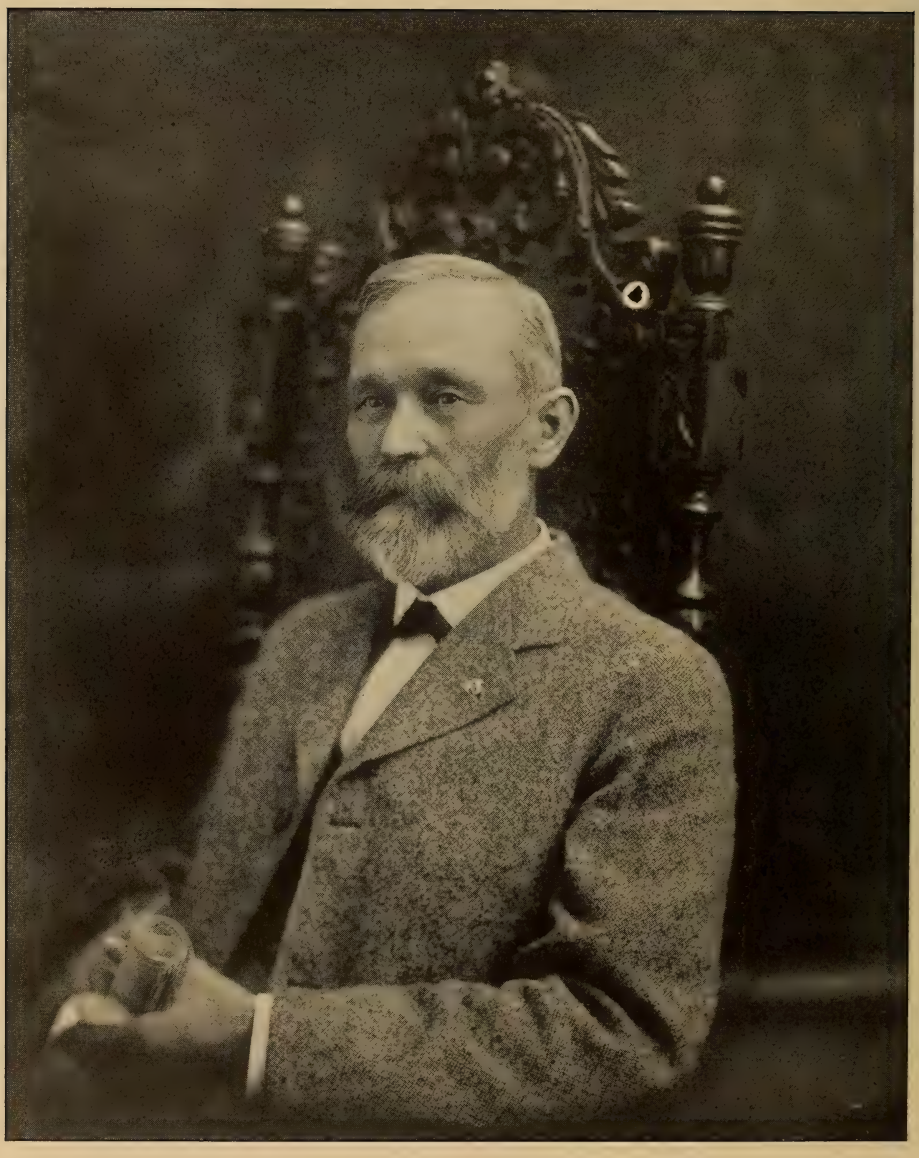
Gas from Wood in the Manufacture of Steel—1902.

Upon coming to the United States, in 1875, Dr. Douglas spent several years in working out metallurgical processes and developing further the well-known "Hunt and Douglas" patents for wet extraction of copper, and in reporting on mines. He then entered into an arrangement with the firm of Phelps, Dodge & Co., which resulted in the acquiring, by the latter, of the Copper Queen and other mining claims in Arizona, which have been developed under his management and have proved most remunerative. Traffic requirements led first to the building of branch railroads, then to the El Paso & Southwestern road, and others, including Mexican connections, aggregating some thousands of miles of trackage. Then came the founding of a great smelting centre at Douglas, Ariz. Under the presidency of Dr. Douglas, these interests are continually expanding until they include not only the development of other industries in Arizona and New Mexico, but the investment of millions in Northern Sonora. In the boldness of conception and initiation and in the thoroughness of execution, all these enterprises have displayed the great optimism, as well as business ability, which have characterized all of Dr. Douglas' ventures of the last two decades. Nor has his optimism failed of justification, for these railroad, smelting and mining enterprises are among the most profitable of similar investments on the continent. The most modern devices have been adopted in mills and smelters; for instance, he was the first to adopt for the generation of electrical power in mines and smelters very large gas engines, using wood for making gas in a Loomis producer, and in the early adoption of some of the most recent improvements in smelting and mining—such as the trough copper converter.

While under the presidency of Dr. Douglas, these enterprises have been financially successful, and while they have brought to him honour and wide professional fame, there is a feature dominating all of them which is more notable and worthy of record.

One cannot conceive of Dr. Douglas remaining the technical head of an enterprise tainted in any way with stock jobbing, unfair treatment of employees or double-dealing of any sort. Fortunately for him, his associates have been men of similar ideals, deeply sympathizing with the high motives which actuated their technical associate in all of his efforts for the uplifting and comfort of miners and other employees.

Dr. Douglas has twice been elected president of the American Institute of Mining Engineers, and is a member of many prominent societies of Europe and America. He has always stood for free trade in ideas, and his mines and works are open to the student, as well as to his brother engineers. He is never too busy freely to give to any one sound advice and the results of his experience that many others feel justified in keeping to themselves.



MINARD LEFEVER HOLMAN

PRESIDENT OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

SEE PAGE 404

CASSIER'S MAGAZINE

VOL. XXXIII JANUARY, 1908 No. 3

THE DEVELOPMENT OF TORPEDO CRAFT

By Archibald S. Hurd

AS a result of the war in the Far East, we are on the eve of a great development in the torpedo flotillas of all the leading naval powers. During the contest between Japan and Russia the Japanese fleet illustrated the use which might be made of torpedo craft as weapons not merely acting on the defensive, but pursuing an active offensive policy. When the war broke out and Admiral Togo assumed command of the whole of the naval forces of Japan, he incorporated in his high seas fleet flotillas of torpedo craft containing practically all the available vessels in the Japanese Navy. In heavy seas many of these small ships were taken the six hundred miles journey to Port Arthur, a neighbouring island being seized to act as a "flying base." It came as a surprise to not a few naval observers, who had been for years depreciating the rôle of the torpedo craft, to find that the Japanese admiral, instead of leaving these vessels behind him to defend the Japanese coasts against possible raids, had formed them into flotillas for oversea work. The war broke out in the early days of February, 1904, when the cold was intense and the seas running high; but nevertheless these frail ships—frail in comparison with battleships and cruisers—were taken to Port Arthur to act an important part in the scheme of Japanese operations. It is unnecessary to recall the measure of success which attended the torpedo operations. The Japanese had had little opportunity of practice, and the temperature of the sea and the unfavourable weather militated against a full measure of success. As the war progressed, however, and the weather improved, the Japanese officers and men, who revealed a devotion to duty which called forth the admiration of the world, showed how effectively even the smallest craft can be used when acting far away from their home ports and dependent upon the meagre resources of an improvised "flying base." The development of the struggle showed the advantage of high speed and size. High speed, to enable the officer in command to gain the tactical advantage during a fight, and large size in order to enable the vessels to maintain their speed even in heavy weather.

The efficiency of the torpedo, revealed during the war, has led to a complete change in naval construction. The recent evolution in battleship design throughout the world has been due to the increased effectiveness of this arm. In the actual condition of war it was found that

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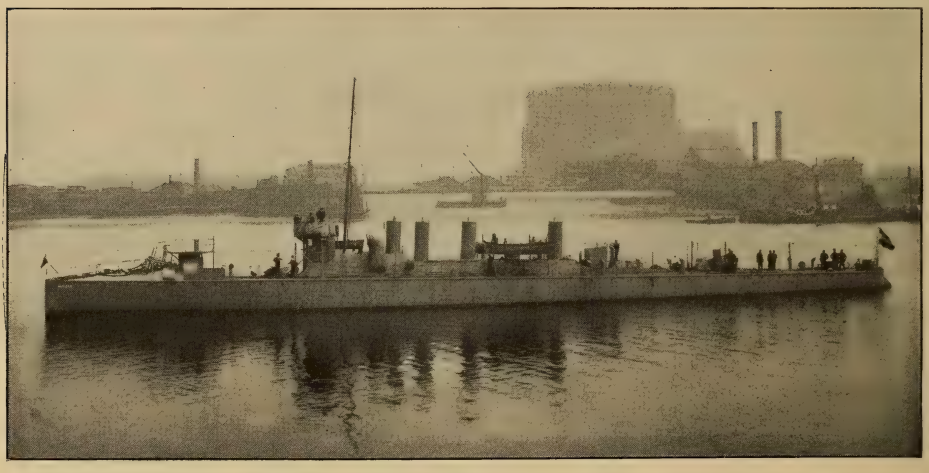
JAPANESE DESTROYER SHIRAKUMO. LENGTH, 216′ 9″; 7,648 H. P.; SPEED, 31.81 KNOTS. J. I. THORNYCROFT & CO., LTD.

actions had to be fought at a much greater range than had been anticipated, owing to the danger of effective torpedo attack. The modern torpedo has been so greatly developed that it can no longer be regarded with skeptical indifference. The conclusion that battleships and cruisers in action would be kept far distant from one another by the fear of the torpedo has led to a complete change in the armament of what are now styled "capital ships." The typical battleship of the latter years of the last century carried four 12-inch guns and twelve to fourteen 6-inch quick-firers. Once it had been decided that battleships and large cruisers could not close to short range owing to the menace of the torpedo, inquiry naturally followed as to the utility of carrying as small a weapon as the 6-inch gun, firing a shell of 100 pounds. The solution of the problem was assisted by the development in gunnery which followed upon the adoption of Rear-Admiral Sir Percy Scott's methods

H. M. S. MOHAWK. J SAMUEL WHITE & CO., LTD. EAST COWES ISLE OF WIGHT

TURBINE DESTROYER DERWENT. SAME TYPE AS WAVENEY AND EDEN. R. & W. HAWTHORN, LESLIE & CO., LTD. HEBBURN-ON-TYNE

for controlling the fire from a position aloft. The principle of "fire control" is an old one, which Sir Percy Scott himself tried with success many years ago when he rigged up in a vessel in which he was serving a station on one of the masts, from which the range was passed to the gunners below. A few years ago the utility of fire control was at last generally admitted in the British Navy, and apparatus was constructed for controlling the various types of guns carried by battleships. It was found that the more various the armament the more difficult and complicated was the problem of controlling the fire, as each type of gun required special provision to be made. Consequently, when the menace of the torpedo suggested that the 6-inch gun would prove ineffective for battle, it was but a short step to the decision to build ships carrying only one type of armament, and that the most powerful. Thus the British authorities came to evolve the battleship *Dreadnought*, carrying only one calibre of gun, firing an 850-pound shell. Experiments confirmed the virtue of this design, and in all the navies of the world ships embodying generally the same principles are now in course of construction. They are the gunnery officer's reply to the menace of the torpedo—one type of big gun for battle and one type of small quick-firer for dealing with torpedo craft. Subsequent developments have served to confirm the view that, in future, "capital ships" will fight at extreme ranges, at which only the heaviest guns, ranging from the 12-inch down to the 9.2-inch, can be brought effectively to bear so as to inflict serious damage. Sir W. G. Armstrong, Whitworth & Co. have applied to the torpedo a principle which has for many years been generally recognized as desirable, but has hitherto not been found practically possible. Inventors have sought for years to overcome the loss of heat which arises from the expansion of air used in the propulsion of the torpedo. The Elswick firm have patented what is styled "the Elswick separate vessel heater" for torpedoes, and at the same time, in conjunction with Messrs. Vickers' Sons & Maxim, they have obtained control of the extensive Whitehead torpedo factory at Portland. This new device confers upon the torpedo a hundred per cent. more power than it has had hitherto. It has been tested in actual practice, and it has been found that, with the Elswick heater, the 18-inch torpedo maintains a speed of upwards of 40 knots for



AUSTRIAN TORPEDO-BOAT DESTROYER HASZAR. SPEED, 28.537 KNOTS. YARROW & CO., LTD., POPLAR

H. M S. TORPEDO-BOAT DESTROYER TEASER. J. SAMUEL WHITE & CO., COWES, ISLE OF WIGHT

1,000 yards, of 37 knots for 2,000 yards, of 30 for 3,000, and 27 for 4,000 yards. The adoption of this device, in association with the proved effectiveness of the gyroscope, will compel large ships of war to fight their actions at even longer ranges than was considered probable even when the *Dreadnought* was designed, and it is now certain that unless they are to come within the sphere of the torpedo menace they must never approach nearer than 4,000 or 5,000 yards. The evolution of the torpedo has thus reached a stage at which it has completely changed the design of the large ship of war throughout the world, and the realization of this fact is leading designers of torpedo craft generally to devote attention to the construction of special ships better designed for the effective use of this newer and deadly arm.

The Japanese naval authorities have been among the first to take advantage of the lessons of the war as to the design of torpedo craft. Since the commencement of the operations against Russia not a single torpedo boat—small, frail and slow—has been laid down. Prior to the

RIVER CLASS OCEAN-GOING DESTROYERS. WHITE & CO.

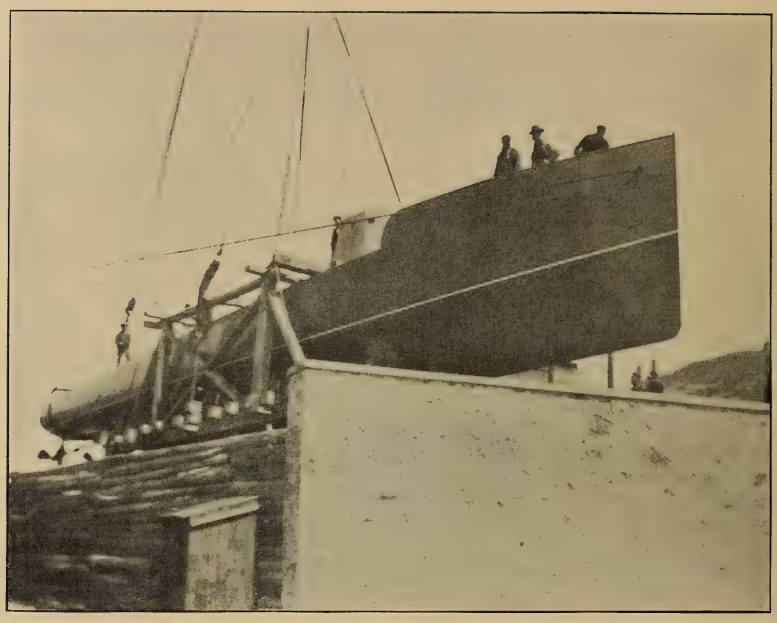
war fifteen torpedo boats had been built with a displacement of 137 tons and 4,200 horse-power, but since hostilities this design has not been repeated. During the progress of hostilities the general usefulness of the large, swift torpedo craft built by Messrs. Yarrow & Sons, at Poplar, and by Messrs. Thornycroft & Co., at Chiswick, was amply demonstrated. These British-built ships are far more valuable units than little ships, whose radius of action is necessarily all the more restricted the higher the legend speed. Another modification which has been made by the Japanese in their later torpedo craft is associated with the armament. The new boats are provided with two torpedo tubes only, as before, but in place of one or two 12-pounders and from two to five

ONE OF TEN GAS-POWER TORPEDO BOATS BUILT FOR THE RUSSIAN GOVERNMENT AT SEVASTOPOL BY LEWIS NIXON, OF NEW YORK

varied in displacement from 307 to 373 tons, and the horse-power from 5,400 to 7,000. Even before the conclusion of hostilities, when the lessons of the conflict began to be garnered and applied, Japan put in hand new ships, and since the commencement of the war she has built and completed thirty-four torpedo craft, with a displacement of 374.5 tons and indicated horse-power of 6,000, giving a trial speed of 29 knots. Vessels of this size are able to go anywhere and do anything, and 6-pounders the new destroyers mount six 12-pounder guns. It was discovered that the bursting charge of the 6-pounder gun was not sufficiently powerful, and, in spite of the increased weight entailed, the new vessels have, therefore, a uniform armament of 12-pounders.

Further indication of the importance which is now attached to torpedo craft is supplied by the German Navy. Under the Navy Act of 1900, it was proposed to lay down in the following sixteen years sixteen divi-

H. M. S. MERCURY II. YARROW NAPIER PETROL TORPEDO BOAT. SPEED, LIGHT 25 KNOTS; SPEED CARRYING 3 TONS, 24 KNOTS; RADIUS OF ACTION, 250 MILES



PREPARING TO LAUNCH A NIXON GAS-POWER TORPEDO BOAT AT SEVASTOPOL, RUSSIA

sions of torpedo craft at the rate of one division a year. Five of these divisions had already been begun when the amending Act of 1906 was passed, and in this, in place of the eleven remaining divisions of comparatively small craft, as originally proposed, approval was taken for the building of twenty-four divisions, each division consisting of six vessels, and thus ensuring the laying down between 1906 and 1917 of no fewer than 144 torpedo craft. In Germany, as in Japan, the tendency is towards increased size and power. Under the Act of 1900 the construction of torpedo boats had entirely ceased, and attention had been directed towards the development of efficient destroyers. After the passing of the Act of 1900 twenty-four boats were laid down of 350 tons displacement, with from 5,400 to 6,500 indicated horse-power, giving a trial speed of 26½ to 28 knots an hour. These vessels carry only three 3-pounder guns. Under the amending Act much larger ships are being constructed, with a displacement of 530 to 560 tons, and an indicated horse-power of 10,000, which is expected to give a speed of 30 knots, and they are to be provided with a somewhat heavier armament, consisting of four 6-pounder guns. It will be seen that the increase in displacement in German destroyers is largely devoted to greater strength and higher speed, and, in comparison with the most recent Japanese types, they are distinctly inferior in gun

LAUNCHING A NIXON TORPEDO BOAT IN RUSSIA WITH A CRANE

A NIXON GAS-POWER TORPEDO BOAT AT FULL SPEED IN THE BLACK SEA

power. It will now be interesting to watch the gradual abandonment of the 6-pounder in favour of the 12-inch gun.

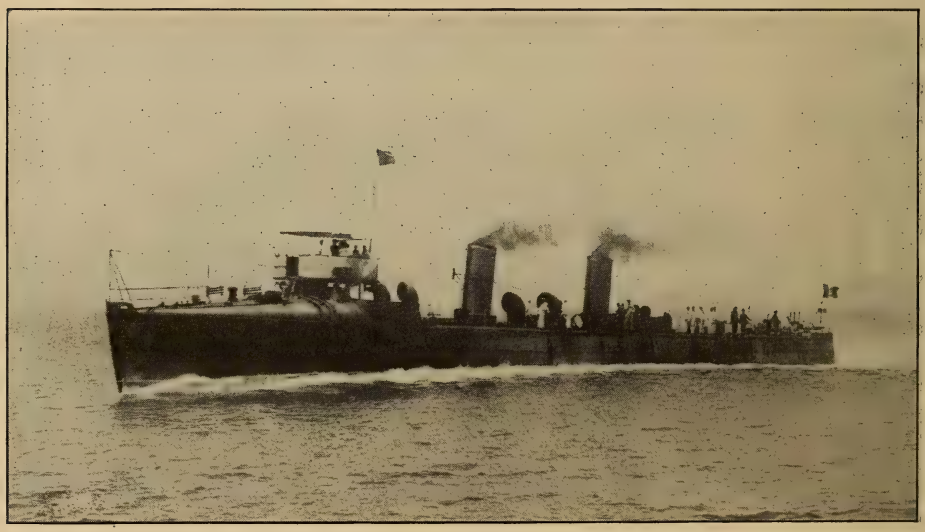
In warship design, however, the British naval authorities have shown that they are not behind any of the rival powers, not even including Japan. Every one of the British firms which have devoted themselves specially to the construction of small, swift vessels holds a pre-eminent position, both for the ingenuity of design—for the Admiralty rely largely on the enterprise of private yards—and the stability and reliability of output, for torpedo craft require a nicety of workmanship which is not called for in the creation of larger types of men-of-war. There is no doubt that the British builders of these special craft obtain more satisfactory results on a smaller displacement than foreign builders on the European continent. For over thirty years at least three firms have held a supreme position in the world as builders of these particular craft. As long ago as the early seventies the great Poplar and Chiswick firms began the development of torpedo boats, and then Messrs. J. S. White, of Cowes, and, later still, Messrs. Laird, turned their attention to this work. Even these early boats, varying in length from 113 to 130 feet, were sent in perfect safety to far distant parts of the world, travelling under their own steam to China, Australia and India, and two of the Yar-

FIRST-CLASS TORPEDO BOATS OPHIR, PANGRANGO AND RINDJANI, BUILT FOR ROYAL DUTCH GOVERNMENT BY YARROW & CO., LTD.

The boilers in these vessels are fitted with oil burners giving an increase of 2 knots in speed for short periods

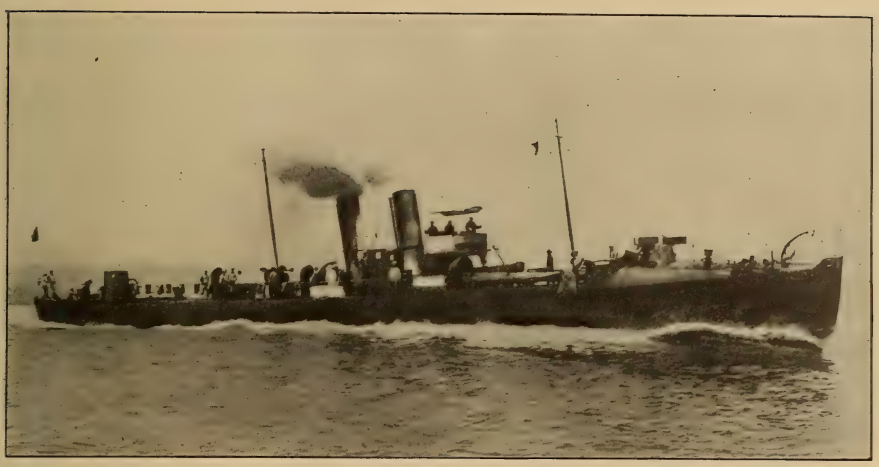
row boats undertook the long voyage from England to Vancouver Island, an achievement which showed conclusively not only the character of the labour put into these craft, but their general stability in heavy seas.

The story of the development of the destroyers was admirably and succinctly recorded in a lecture before the Institute of Marine Engineers by Fleet-Engineer George W. Harding, now retired. He recalled that the precursor of the destroyer class, which had since found its way in large numbers into all the navies



ROYAL ITALIAN TORPEDO-BOAT DESTROYER ESPERO. LENGTH, 208′; 6,000 H. P.; TRIAL SPEED, 30.75 KNOTS. CONSTRUCTED BY C. & T. T. PATTISON, NAPLES, TO DESIGNS OF J. I. THORNYCROFT & CO., LTD.

of the world, built for the most part on the lines laid down by British builders, was evolved in 1884. Hitherto the plan had been to give torpedo boats an alternative armament, so that half of the boats might be employed for firing torpedoes, the others acting as torpedo boat destroyers, the boats armed with the small guns resisting attacks of torpedo boats. Perhaps the first approach to the destroyer was the production of Messrs. J. S. White, of Cowes. This vessel, which was added to the British Navy in 1885, was 150 feet long. She was fitted with twin screws and, as the commodore of the flotilla, she did good work. Another vessel, 200 feet long, and of 2,900 horse-power, named the *Sea Serpent,* was also laid down by the same firm in 1885, and obtained a speed of 23.8 knots with a load of 20 tons, and 21.5 knots with a load of 90 tons. About 1893 the British Navy gave orders for torpedo boats which were to be of lighter speed than hitherto, whilst carrying a greater load. Some of these boats were fitted with locomotive boilers, but the trials showed that, for that particular service, the water-tube boiler was to be preferred. With the very thin plates used in the construction of the hulls of these boats it was absolutely necessary to manipulate the plates, in order to give the requisite strength to resist any alteration of form. A 5-pound plate, one-eighth of an inch thick, was a very limp object when received from the cogging mills, but after it had passed the levelling slab and had been levelled, it became very stiff. Its actual tensile strength was not in any way altered, but its strength to resist bending was very much increased, the levelling, or "planishing," rendering the plate extremely stiff. In the 27-knot de-



FIRST-CLASS ITALIAN TORPEDO BOAT CASSIOPEIA. LENGTH, 165′; SPEED, 26 KNOTS. BUILT BY C. & T. T. PATTISON, NAPLES, TO DESIGNS BY J. I. THORNYCROFT & CO., LTD.

stroyers, built of galvanized mild steel plates with tensile strength of 30 tons, the weight of the garboard strake was six and one-half pounds, the sheer strake nine pounds and the deck plating six and one-half pounds and eight and one-half pounds per square foot. These 27-knot destroyers were of various lengths, from 180 feet to 190 feet, the horse-power varying from 3,700 to 4,800. The *Havock,* built by Messrs. Yarrow & Co., the first of these destroyers, obtained a speed of 26.2 knots. That vessel, with a displacement of 240 tons, showed what could be done with the least displacement, with the least power, and with the least coal consumption towards carrying the necessary armament at the requisite speed. From 1891 to 1896 the trials of the 27-knot destroyers were chronicled in the newspapers, and each seemed to go one better than the other. To the *Boxer,* built by Messrs. Thornycroft, belonged the honour of attainiug the highest speed on the measured mile, that vessel reaching 29.1 knots with 4,490 horse-power. In the matter of coal consumption, the record

TORPEDO-BOAT DESTROYER THYELLA. BUILT FOR THE GREEK GOVERNMENT BY YARROW & CO. SPEED, 31.79 KNOTS

TORPEDO BOAT BOYNE. 220′ LONG; SPEED, 25½ KNOTS. R. & W. HAWTHORN, LESLIE & CO., HEBBURN-ON-TYNE

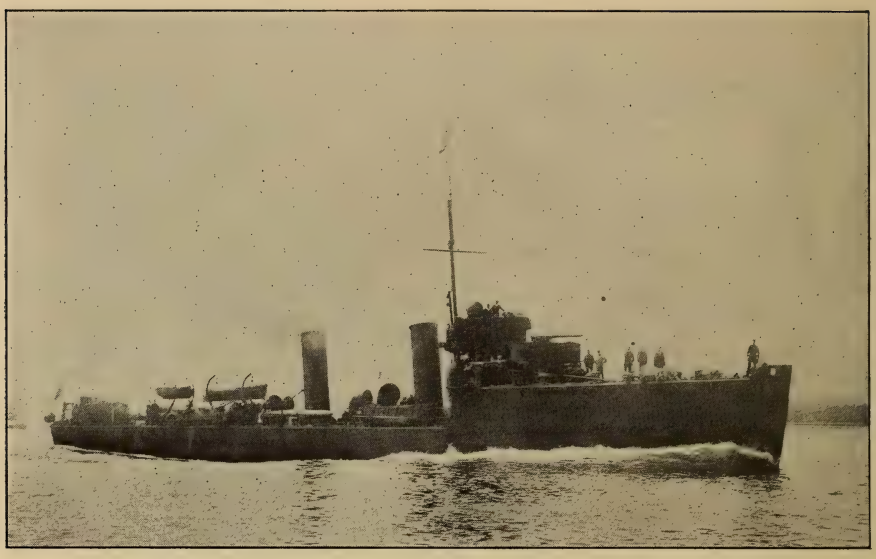
was made by the *Hornet,* built by Messrs. Yarrow & Co., which burned 9,322 pounds per hour, giving 27.6 knots throughout her trial.

As regards boilers, it was proved at an early stage, as Mr. Harding has recorded, that the locomotive type gave excellent results up to a certain rate of coal burning. At slow burning they were very economical, but when they were forced the tube ends could not be depended upon to remain tight. This trouble was not experienced in water-tube boilers, of which practically all were superior to any type of locomotive boiler which had hitherto been used, when forced to the utmost extent of their coal-burning capacities. Nevertheless, the locomotive boiler gave 1 horse-power for 1.33 square feet of heating surface, as against a maximum of 2.58 square feet in a water-tube boiler. Such was the early development of the destroyer in England, before the adoption of the Parsons turbine and oil fuel.

Since the conclusion of the war in

H. M. TORPEDO-BOAT DESTROYER EXE. LENGTH, 225′; SPEED, 25½ KNOTS. PALMERS SHIPBUILDING & IRON CO., LTD., JARROW

H. M. S. COSSAK, 33-KNOT DESTROYER AT PRESENT BUILDING AND SHORTLY TO BE READY FOR TRIAL. CAMMELL LAIRD & CO., LTD., BIRKENHEAD



H. M. S. COLNE. LENGTH, 225′; SPEED, 25½ KNOTS. J. I. THORNYCROFT & CO., LTD

the Far East rapid progress has been made in the development of British torpedo craft, and the credit has been mainly due to the intimate technical skill of private firms and the spirit of enterprise, allied with accurate scientific knowledge, which they have exhibited. The unfortunate *Cobra* incident, whatever its cause, acted as a check for a time upon the progress in the design of torpedo craft, and resulted in the abandonment of the familiar 30-knot type and the construction of the vessels which form what are known as the "River class." These destroyers have an average displacement of 550 tons, carry four 12-pounder guns, are fitted with the two 18-inch tubes and, with about 7,000 indicated horse-power, have proved themselves to be good for rather over 25 knots on actual service. Of these thirty-four vessels, six have been built by Messrs. Yarrow, nine by the Palmer Shipbuilding Company, seven by Messrs. Cammel, Laird & Co., six by Messrs. Hawthorne, Leslie & Co., four by Messrs. Thornycroft & Co., and two by Messrs. J. W. White & Co. When they were first ordered they were somewhat hastily condemned by naval opinion as being too slow, but experience in actual service has shown that, although their nominal speed is only just over 25 knots, they are actually able to steam under average conditions as fast as the earlier boats with a nominal speed of 30 knots, and behave much better in a seaway, while they have proved to be the most economical torpedo craft in the service, with an actual radius of action at slow speed of about 2,000 miles. They carry 30 tons more coal than the German or Japanese destroyers. These British vessels represent the development following immediately on the *Cobra* disaster, and it is satisfactory to know that the effects of this unfortunate incident are at last disappearing. The fact is, that torpedo craft necessarily require very great care not only in their construction, but in their management in service, and types are now being obtained which mark a great advance in all respects.

The British Admiralty's new policy differs essentially from that of Germany and Japan. The British naval authorities are not content to put all their money into one type of torpedo craft. No doubt this posi-

tion is due to the multifarious duties which devolve upon the British Navy and the wide distribution of ships in various parts of the world which still obtains. The torpedo craft which are now in hand may be roughly divided into three classes; the first consists of a large type of ocean-going destroyer, the second of smaller vessels, originally styled coastal destroyers and now known as torpedo boats, and the third of submarines. The consideration of development of the last type must be postponed until a later occasion. In the meantime, the two main types of destroyers which are being added to the British Navy in large numbers furnish illustrations of the continued enterprise of British builders.

From the time of the building of the earliest torpedo boat, exactly thirty years ago, down to the experimental ship *Swift,* which is now under construction by Messrs. Cammel, Laird & Co., there has been a rapid advance in speed which has been almost doubled. This advance has been made in spite of more stringent regulations imposed by the Admiralty as to the strength of hull and as to the conditions of trial, and has been due in no slight measure to the introduction of the Parsons turbine engine, the use of liquid fuel, and the success which has attended the employment of high tensile steel. At the recent Engineering Conference, Mr. Alfred Fernandez Yarrow, M. Inst. C. E., pointed out that before the use of this high tensile strength in the construction of torpedo boats and destroyers, ordinary mild steel was adopted. Yolla metal, which the firm used in the hull of the *Sokol,* had a tensile strength of 37 tons to 44 tons per square inch, and an extension of not less than 15 per cent. in 8 inches for plates of 3/16-inch thick and over. The present Admiralty practice is to adopt steel of 37 tons to 43 tons per square inch, with a minimum elongation of 8 inches, of 15 per cent. for plates of $7\frac{1}{2}$ pounds and over, 14 per cent. for plates of 5 pounds and up to $7\frac{1}{2}$ pounds, 12 per cent. for plates $3\frac{1}{2}$ pounds and up to 5 pounds.

Mr. Yarrow added that it was found that in the material used in the *Sokol,* introduced by Mr. James Riley, they could get 15 per cent. elongation with plates of appreciably less than $7\frac{1}{2}$ pounds per square foot. With material of the same ductility, the thinner plate will have a reduced elongation. This material took

H. M. FIRST-CLASS TORPEDO BOAT NO. 110. LENGTH, 166′; BEAM, 17′ 3″; DRAUGHT, 8′ 3″; I. H. P., 900; TRIAL SPEED, 25½ KNOTS

the place of the mild steel which had been previously used, and which had a tensile strength of 26 to 30 tons per square inch, with an elongation of 20 per cent. in 8 inches for plates 3/16 inch thick. After numerous tests, Messrs Yarrow felt justified in reducing the thickness customary at the time to the extent of 12 per cent., thus effecting an appreciable saving in displacement. "In connection with this subject," Mr. Yarrow pointed out, "it should be borne in mind that in structures such as those we are dealing with having the plating very thin, it is the buckling strains that have to be feared most, that is to say, assuming a vessel supported on two waves at the ends, it is the buckling of the deck that has to be specially guarded against as most likely to cause failure; and, therefore, a material which secures the greatest stiffness is undoubtedly to be preferred, provided other important qualities are not too much sacrificed. This stiffness can be secured not only by using steel of higher tensile strength, but by adopting a form other than flat, for curvature secures stiffness, more particularly if that curvature is obtained by hammering cold and not by bending hot. In dealing with thin plating it is in those parts subject to buckling strains that the greatest care has to be taken in the workmanship, because if the plating be not exceedingly fair and in a line with the strain to be resisted, further distortion may easily take place, and the more the distortion the weaker the form of the plate becomes to resist compression; on the other hand, when a plate is not fair and is subject to tension, the more the strain the straighter the plate becomes, and is thus able the better to withstand that strain. Consequently, accuracy of workmanship is of paramount importance in those parts of a hull of a lightly constructed vessel which are subject to compressive strain. In fact, it is quite impossible to make any reliable calculations as to what thickness is necessary to resist compression in thin structures, except on the assumption that the workmanship is exceptionally good."

Mr. Yarrow also noted that it had been the practice at times to use high-tensile steel for certain parts of the hull and mild steel for others. He regarded this as not altogether a desirable combination, because to have in the same structure two classes of material possessing different properties, especially different amounts of elasticity and elongation, led to the elastic limit of the one being passed before the limit of elasticity of the other was approached; whereas the aim should be that all parts of the same structure should offer the maximum resistance simultaneously, and by so doing secure collectively a greater resistance to distortion than if the giving way were at varying periods. He claimed that the frames should be also of high-tensile steel, because they would be stiffer to resist distortion. In a thin, hollow structure like a torpedo boat before the vessel actually collapses by the strains of the sea, due to rapidly alternating tension and compression, in all probability the sides of the vessel will have a tendency to become distorted, and anything that can keep the hull in shape and avoid this change of form naturally offers security against collapse. The hull of a torpedo boat or destroyer is, in a measure, like a suspended bicycle wheel, the spokes of which are all subject to tension.

The adoption of this high-tensile steel, in spite of the increase in the rivet area to the extent of about 50 per cent., has led to very considerable augmentation of speed, and there is no doubt that the Admiralty's stringent rules would have handicapped builders had it not been for the advantage obtained by the use of tensile steel. Though the Admiralty's initial efforts for greater strength of hull was due, in some measure, to the outcry which followel the loss of the *Cobra*—an

JAPANESE DESTROYER USUGUMO. LENGTH, 216′ 9″; SPEED, 31.8 KNOTS. J. I. THORNYCROFT & CO., LTD.

TURBINE DESTROYER VELOX. R. & W. HAWTHORN, LESLIE & CO., HEBBURN-ON-TYNE

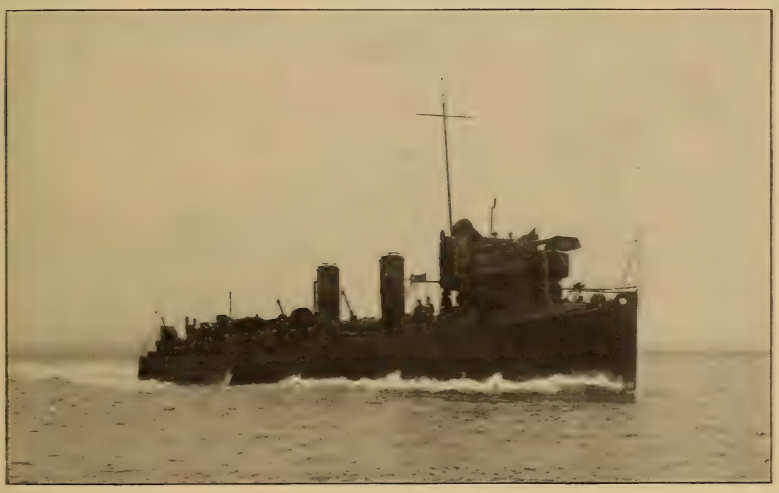
outcry which was mere ignorant hysteria—the result has been altogether admirable in leading to the development of a higher class of ship, with better sea-going capacity. The tabulated statement given recently in a paper by Professor Welch indicates the increase in displacement which has taken place. The improvement in sea-keeping qualities of the later craft has more than counterbalanced the temporary check which at one time occasioned considerable annoyance to the firms engaged in this class of construction. The aim of the Admiralty is now to produce vessels for general service capable of keeping the seas for long periods and ensuring a large measure of comfort to the crews. In order to meet these conditions the latest types of destroyers in particular have been provided with high forecastles, which render the ships drier, and greater coal bunker capacity has been provided for, and gradually a type of vessel has been evolved which is far less frail than the early types and much more serviceable. No doubt the Admiralty's stipulation as to strength of hull goes far beyond the margin of safety, but that is an error on the right side, in view of the nervous state of public opinion whenever any mishap occurs to one of these small craft.

A great deal of the additional weight now put into the hull has been saved owing to the introduction of turbine engines and the use of oil fuel. In his recent lecture, Professor Welch pointed out that, with reciprocating machinery, the possible I. H. P. obtained per ton of total machinery had not greatly increased since 1877. For example, in the *Lightning,* which was of only 28½ tons displacement, 39 I. H. P. was developed for each ton of machinery, as against an average of, say, 40 to 42 for the 27-knot and 30-knot destroyer type, of displacements ranging from 240 tons to 350 tons on trial. In the *River* class, the power per ton was distinctly less than this (about 33 in the case of vessels built by Messrs. Cammell, Laird & Co.), due partly to the restriction of revolutions below the limit used in the preceding types. As Professor Welch remarked, the *Lightning* was a special vessel of limited radius of action intended for operations near the coast, whereas the later destroyer types are fitted for work at sea, with correspondingly greater strain on machinery endurance, so that the advances in machinery design have been very much greater than a cursory glance at the figures given would indicate. These figures gain additional significance when compared

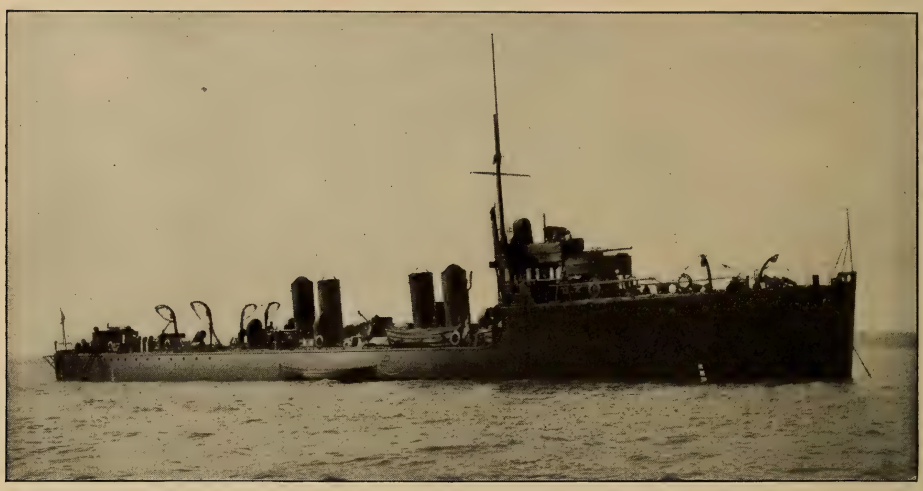
with those for fast vessels of other types: in the *Rattlesnake* class of torpedo-gunboat, for example, about 21½ I. H. P. was developed per ton of machinery, whilst in some of the fastest cross-Channel passenger steamers the corresponding figures are 10 to 11 I. H. P. per ton, and this is also approximately the result obtained in some of the latest cruisers. The *Turbinia*, a special vessel 100 feet long and displacing 44½ tons on trial, marks, with her rotary engines, a notable advance, no less than 72 H. P. being estimated to be produced per ton of machinery. Necessarily this standard was not reached in the larger vessels of the sea-going destroyer type subsequently built and fitted with turbine machinery, but the results have been distinctly in advance of those obtainable with reciprocating engines, whilst a still better performance may be reckoned upon in the latest vessels provided with turbines and with boilers using oil fuel. Even from the point of view of comfort, as Professor Welch also insisted, the introduction of oil fuel has secured important advantages. The operation of fueling the ship and furnace is less laborious and more cleanly than before, whilst the hot cinders which frequently fell, during a full-speed trial, on the deck of a destroyer using coal, are, in the latest vessels, conspicuous by their absence.

The satisfactory feature of the latest types of destroyers is their comparative cheapness. In view of the growth in the size of the ocean-going type, the higher speed obtained, the large quantity of oil fuel carried, from 73 to 95 tons, the individual outlay of about £140,000 for each ship cannot be regarded as excessive. Of course, the *Swift* will cost about twice this sum. This additional cost is largely the price paid for phenomenally high speed; but, at the same time, the *Swift* is more heavily armed than the ocean destroyer type, since she is to carry four 4-inch quick-firers instead of three 12-pounders. A type of ship midway between the *Swift* and the original ocean-going vessels has been ordered from Messrs. White & Co., at Cowes, and Messrs. Thornycroft & Co., of Chiswick. These two vessels, the *Saracen* and *Amazon*, will displace 890 tons, will have a particularly high forecastle, and will carry two 4-inch weapons.

At the same time, the Admiralty have realized that the British Navy requires a large number of ships of



NEW TYPE COASTAL DESTROYER TRAVELLING AT A SPEED OF 27 KNOTS. J. SAMUEL WHITE & CO., COWES



H. M. TORPEDO-BOAT DESTROYER GALA. YARROW & CO., LTD. POPLAR

more limited radius of action, not for service with the fleets at sea, but mainly for coast defense, particularly in the neighbourhood of the great naval arsenals. For duty in the neighbourhood of fixed bases, ocean-going destroyers are unnecessarily large and expensive. For this reason the coastal destroyer type was evolved, costing rather less than one-third the sum expended upon a large-type destroyer. Twenty-four of these vessels have been built. One of the first to be completed for sea was the *Gadfly,* built by Messrs. Thornycroft. Though designed for a speed of 26 knots, she actually attained 27.2 knots on the measured mile, and a consumption trial of twenty-four hours at low power showed that a speed of 12 knots could be maintained for the expenditure of less than 9 tons of oil. This achievement means that the *Gadfly* and her sisters have a radius of something over 1,200 miles at economical speed, since, small as they are, they are provided with a capacity for carrying 40 tons of oil.

Experience has already shown that the introduction of the turbine in association with oil fuel not only leads to the elimination of the old smoke trouble which occurred in some boats, but leads to a very considerable economy in the personnel. It is calculated that one of these so-called coastal destroyers could be run in emergency single-handed. The vessels of this class which have been completed for sea have already given most satisfactory results. They have proved themselves to be very handy, hold their speed well, and are far more comfortable than the old type of torpedo boat. Though they are now classified as torpedo boats, they actually displace more water than the early destroyers, and mounting, as they do, two 12-pounder guns, they may be more legitimately regarded as destroyers than as torpedo boats.

The small size torpedo boat is not being built in the British or foreign fleets at present, but in view of the success which has already been achieved by Messrs. Yarrow & Co. in fitting motor engines to small craft of the torpedo type—a success which has already led the Admiralty to place further orders with the firm—it would be unwise to regard small craft as completely and for all time eliminated from the fleet. It is anticipated that the motor engine will lead to a high speed on a relatively small displacement, and that it may be possible to evolve a suitable craft for coastal defense at even a less cost than the new type of coastal destroyer.

Messrs. Yarrow have already furnished the government with a boat only 15 feet long, which is silent when under way, can attain a speed of 25 knots, and has two torpedo tubes; the crew consists of only two men. It is intended to test the capacity of this design of craft in a larger boat, 40 or 50 feet long. Under the Admiralty's encouragement, there is reason to hope that eventually the navy may obtain a particularly effective small, swift motor-propelled torpedo boat in every way suitable for coastal defense, and exceedingly cheap. A couple of years ago it was conjectured that, owing to the success of the submarine, above-water torpedo boats would become obsolete. There is already good reason for revising this too hasty verdict. Submarine craft will never realize as high speeds as ordinary surface craft, and if eventually a motor boat is evolved with a rate of steaming from 35 to 40 knots an hour, there is no doubt that such swift and comparatively cheap craft will be welcome in the fleet for subsidiary defense service near a fixed base.

Under the British naval programme for the present year five more ocean-going destroyers and twelve even larger first-class torpedo boats have been ordered, and now that the Admiralty have evolved types of torpedo craft which meet with the general approval of naval officers, there is reason to anticipate that in future years the orders will be far more numerous than they have been hitherto. Now that sails have disappeared, torpedo craft offer the best avenue for training the personnel, and consequently these craft are kept at sea for much longer periods than was the case a few years ago, and this necessarily means a large proportion are always in need of repair. For this reason, it is essential that the Admiralty should always have a large margin over and above the actual requirements of the fleet. Probably this margin should amount to not less than 25 per cent., and in view of the age of many of the destroyers still serving in the flotillas, active steps will have to be made to replace them. At the same time, measures must be taken to raise the standard of strength in this arm of the British service much above the present level, in view of the active construction which is being pursued abroad, and especially in Germany. It is intended to build twenty-four destroyers in each year covered by the present German Navy Act, and about the same number will probably be added to the French fleet. If the British two-power standard in torpedo craft is to be maintained, it will, therefore, be necessary to pursue a very active shipbuilding policy in this respect.

THE EXPLOSION OF GASES

By John Batey

THE explosion of gases, and their resulting pressure effects, have been utilized to advantage in various ways, more especially in connection with gunnery operations and for the production of mechanical force, in engines of the internal-combustion type, and it is in regard to the latter use that the following subject matter particularly applies.

Much scientific research and experiment has resulted in the formulation of laws, which have been accepted as indicative of the true nature, character and influence of heat upon gases generally, which includes the effect upon air as a vehicle for absorbing heat, also in regard to air as a gaseous combination with fuel of various characters and value.

The magnitude of the effects produced by combinations of air and fuel have been fairly well ascertained, not only in regard to solid fuel, such as coal, but in combination with the gaseous formation produced by the distillation or combustion of fuel, and the latter, in reference to the internal-combustion engine, is of a very problematic character, which is environed round by effects which are difficult to measure or comprehend.

Very careful tests of explosive effects, in which record of time, pressure and other conditional matters have been closely observed, and ample data supplied for various combinations, and these various amalgamations have, in some measure, been consistent with the known elemental properties, in regard to the quantity and specific heats of the compound, from which reasonable deductions have been derived, but the causes by which the effects are regulated are still doubtful and uncertain of application.

In these experiments, the demonstrated effects are a long way from the calculated, theoretical value in which the element of surface and volume play a large part.

By examining minimum and maximum conditions, it may be possible to arrive at some standard of comparison whereby a measured comparison between the calculated and observed effects may be made.

A volume of gas, say one pound weight, contained in the capacity space of a sphere, may be regarded as a maximum volume retained in contact with the minimum amount of envelope surface, and supposing the said volume is compressed into the space, which is one-fourth of the volume of that under atmospheric pressure, then the original temperature—62 deg. F.—has been increased to, say, 458 deg. F., and is held under an absolute pressure of 102.9 pounds pressure per square inch; and assuming the volume of the gas to be the same as air, then one-fourth of 13.14 cubic feet = 3.28 cubic feet, the required volume, which is supposed to contain 1,250 B. T. U. of heat, the specific heat of the gas being 0.259; therefore, 0.259 unit is required to increase the temperature 1 deg. F., and 1,250 ÷ 0.259 = 4,824 deg. F., the temperature of combustion, after the gas has been exploded. Now the temperature of the compression moment, 458 deg. F. plus 4,824 deg. F. = 5,282 deg. F. = the total temperature of combustion, and this is the theoretical condition of the volume

of gas contained in the sphere; that is, presuming that the specific heat value is correct for a constant volume condition, which it is not, because 0.1904 is the true specific heat of such a gas at constant volume. Now 1,250 units ÷ 0.1904 = 6,565 deg. F. plus 458 deg. F. = 7,023 deg. F., the supposed temperature of combustion, under the constant volume conditions, but such a temperature is inconceivable and, it may be said, unreasonable, when read by what occurs, under the condition of applications of heat to a gas, during constant pressure; therefore, the previous determination is accepted for the present, or 5,282 deg. F. = the assumed temperature of combustion.

Metal, say cast iron, is of a low specific heat value; therefore, assuming this to be the material of the sphere, then it must either retain the heat or disperse it; conditionally it may do both, but with water circulating around it the heat, beyond a certain amount, is dispersed; the question is how much.

The answer is the difficulty, but by the aid of experiment and analogy a rate, approximately correct, may be deduced.

Dr. Slaby, Professor Thurston, Mr. Dugald Clerk and others have made such experiments. The two first named experimenters have shown by direct measurement that 52 to 54 per cent. of all the heat credited to a gas engine was found in the cooling water, whilst Mr. Clerk has determined, by trial and inference, that the jacket waste is from 23.5 to 29.3 per cent. of the whole heat, but Mr. Clerk practically assumes the expansion stroke to be adiabatic, or near it; therefore, by inferential methods, Slaby and Thurston's deductions may represent 33 per cent. as being lost during combustion, and the average of Clerk's equal 26.4 per cent., and the mean of 33 + 26.4 ÷ 2 = 29.7 per cent., or say 30 per cent. of the whole heat is lost during combustion in an ordinary cylinder. The volume of 1 pound of gas equals, say, 22,752 cubic inches, and presuming this to be used by an engine with a cylinder 7.25 inches diameter by 7.375 inches stroke, making 296 revolutions per minute, or 74 power strokes, then under a compression to one-fourth of the original volume 76.85 cubic inches is contained in a compression space, and the surface exposed to the volume equal 41.28 +41.28 + 41.98 = 124.54 square inches.

A sphere of similar capacity is about 5 feet 3 inches diameter, or the cube of the diameter × .5236 = capacity, 76.85 cubic inches nearly.

The superfices of a sphere equal the diameter squared × 3.1416 = 88.24 square inches, and as 124.54 is to 30 per cent., so is 88.24 to 21.2 per cent., or the proportional loss of heat.

Now 21.2 per cent. of 1,250 B. T. U. = 265 units, leaving 985 units in 1 pound of gas, from which the temperature of the substances is calculated; therefore, 985 ÷ 0.259 (specific heat) = 3,803 deg. F., and plus 458 deg. F. (the temperature of the compression moment) = 4,261 deg. F., which is presumably the theoretical greatest maximum temperature.

The cylindrical capacity and surface is in proportion, or as 124.54: 88.24 : : 30 : 21.2 per cent., then as 30 : 21.2 : : 3,803 : 2,637 deg. F. + 458 = 3,145 deg. F., the maximum temperature of the substance inside of the cylinder.

Obviously, the heat lost to each square inch of surface per degree of difference per minute must be the same in both cases, because the loss is due to extent of surface; therefore, the rate of transmission per square inch of surface of the sphere implies a similar rate for all surfaces of whatever shape, under similar conditions of time, per degree of difference, and this is practically three units per square inch per minute, due to a temperature of combustion of 4,261 deg. F., which includes the temperature of the compression moment.

It is not necessary to measure out the rate per degree of difference because such a temperature cannot be reached as a working condition in an internal-combustion engine cylinder, because hydrogen dissociates at 3,460 deg. F.; therefore, the above maximum temperature requires qualification.

When a volume of gas is expanding under a constant pressure due to additional heat, part of the heat is converted into work and another part to increase the temperature of the gas. Air has a capacity for heat equal to absorbing 0.2377 units per pound weight, and it does not matter what the pressure may be, because this has been proved under 20 atmospheres of pressure, and it is equally clear that 0.1688 unit is engaged in increasing the temperature and 0.0689 unit is converted into work, in expanding the volume, but 0.1688 unit will not increase the temperature of 1 pound of air 1 deg. F., though 0.2377 unit will; therefore, the capacity of air for heat is 0.2377, whilst the true specific heat is 0.1688, but it requires the larger amount to raise the temperature of 1 pound of air through 1 deg. F.

Under the condition of constant volume the capacity for heat is the same, viz., that 0.2377 unit is required to raise the temperature through 1 deg. F., but only 0.1688 unit is concerned in indicating the increased degree of heat, and the remainder has the same influence upon the substance under a constant volume as it has under a constant pressure; but under a constant volume there is no expansion, yet the conditional effect is similar because work is being performed in keeping the gases asunder, otherwise the increased pressure would liquefy the gas, and that this work of resistance is measurable by the work done at a constant pressure is provable by what is shown on the diagram when the gas held under a constant volume is allowed to expand against a constant pressure.

Under these conditions the temperature derived from the quantities and specific heats by reference to constant pressure is subject to the condition that, out of 0.2377 unit of heat put into each pound of air, only 0.1688 appears as temperature; therefore, the temperature of combustion, if referred to these proportions, becomes as 0.2377 is to 0.1688.

Now for the gases under consideration, the capacity for heat per pound of gas equals 0.259 unit, and the specific heat or the thermal determination is .1904 of this; then as 0.259 : 0.1904 : : 3,803 : 2,795.7 deg. F. plus 458 deg. F = 3,253.7 deg. F., which is assumed to be the maximum indicated temperature of the contents of the sphere. Suppose the cooling water is 180 deg. F., then the difference is between 3,253.7 and 180 = 3,073.7 deg. F, and three units divided by this temperature = .00097 unit, or the rate of dispersion of heat per square inch of surface per degree of difference per minute. Now 0.00097 × 144 square inches × 60 minutes = 8.3 units per square foot per hour per degree of difference, which is closely approximate to the evaporative effect of a boiler furnace.

The given rate of dispersion refers to any shape of envelope of which the sphere represents the minimum loss. The plain cylindrical shape, like the end cut off a cylinder, is 9 per cent. less efficient in saving heat, and pockets added to it to carry the valves still further increase the loss. Various effects may be produced by size and dimension; for instance, three cylinders, compared with two cylinders for similar conditions of compression, stroke, revolutions and power, will lose more heat to the walls than the two-cylinder.

The general deductions of the foregoing argument show that about 30 per cent. of the total heat is lost during combustion, and the remainder, by reference to the several quantities and specific heats of the gases, is referred to as the temperature of combustion. which is a measure of the

whole heat capacity of the gas, whereas the real thermal value, as temperature, is in the proportion of the ratio of the specific heats at constant volume and constant pressure, or 1.36 the ratio.

The first is actual loss, viz., 30 per cent. of the whole of the estimated heat value, and it can be shown that this is about the percentage of radiant heat formation, which in its nature has no direct influence upon the gas, except by conduction from the surface which it attacks or influenced by a restricted area of escape.

The 1.36 ratio reduction equals 26.5 per cent. of the remaining heat which, when referred to the total heat, equals 18.5 per cent.; then the total loss equals $18.5 + 30 = 48.5$ per cent. of the whole estimated heat value.

Mr. Dugald Clerk, in his book on the gas engine, has given the result of a number of experiments in regard to the explosion of gases in a closed vessel for various mixtures.

The observed pressures show considerable variation for succeeding richer mixtures, having regard to the fairly uniform increase of the calculated pressures, but the whole series, as a total effect, may be used as a means of comparison with the foregoing deductions.

The observed and calculated effects have been supplemented by two extra columns, showing the loss due to 48.5 per cent., and the result when this value is deducted from the calulated pressure.

The augmented table is as follows, in which:

Gas Volume.	Air Volume.	Observed Pressure. Lbs.	Calculated Pressure, Lbs.	Reduction 48.5 Per Cent. Lbs.	Result. Lbs.
1	14	40.	89.5	— 43.3 =	46.2
1	13	51.5	96.0	— 46.5 =	49.5
1	12	60.0	103.0	— 49.9 =	53.1
1	11	61.0	112.0	— 54.3 =	57.7
1	9	78.0	134.0	— 64.9 =	69.1
1	7	87.0	168.0	— 81.4 =	86.6
1	6	90.0	192.0	— 93.1 =	98.9
	Total	467.5		Total	461.1

The observed total and the total of the percentage results are within 1.4 per cent., and are, therefore, practically equal, thereby tending to support the argument in regard to the specific heat and heat capacity determinations, and also the value of the loss attributed to radiant heat formation.

As a further comparison, it may be pointed out that other tests of Mr. Clerk fit much more closely to the percentage results when referred to Glasgow coal gas trials, in which the observed pressures are as follows:

Gas.	Air.	Pressures.	Percentage Results
1	13	52 lbs.	49.5 lbs.
1	11	63 "	57.7 "
1	9	69 "	69.1 "
1	7	89 "	86.6 "
1	5	96 "	for 1 to 6 98.9 "

In the foregoing comparison of deductions with experimental results there is furnished a reasonable and conceivable cause from which known effects are produced, being nothing more than a simple natural law which accounts for every problematic issue.

The nature and character of radiant heat formation is such that under increased temperatures, radiant heat declines in favour of convected heat, and this latter is that from which the power factor of the internal-combustion engine is received; therefore, low cylinder temperature cannot be commended, and indeed this is recognized by most heat engine authorities.

It has been declared that if explosion mixtures behaved as perfect gases in which the pressure and temperature is known before the explosion, then the resulting pressure and temperature after explosion would be easily ascertainable. As a practical condition this is possible within reasonable limits, especially as the coal gas is largely diluted with air, of which the residual nitrogen may represent nearly 70 to 75 per cent. of the whole of the continued gaseous volume, and this gas is a vehicle for heat, thereby whatever the reduction of volume may be, it can only be the result of new combinations of, roughly, 25 per cent. of the whole

total volume, such being the practical issue, which is, of course, untrue, scientifically; but, bearing in mind the many disturbing influences at work, the general method of calculating the gases by their weights, and valuing them by the amounts and their specific heats, having regard to the impossibility of holding anything near the total heat value, then the estimation of the temperature by the suggested method, from which the initial pressure may be calculated, may be deemed an approximately close calculation to practical and operative conditions.

The shrinkage of volume which no doubt takes place may be relegated to the value of slipped heat, and assuming this to be 21 per cent. for the ideal minimum surface, or 30 per cent. for the usual working one, then engine efficiency will rest upon the refinements introduced by reference to accurate conceptions of heat values and gaseous volume reductions, but for practical demonstrations the assumption that the gaseous volume is equal to the air volume is within reasonable reach of exactitude.

THE DETROIT RIVER TUNNEL

By James C. Mills

THE CONSTRUCTION OF THE MICHIGAN CENTRAL TUNNEL BETWEEN CANADA AND THE UNITED STATES UNDER THE DETROIT RIVER

THE boundary line between the United States and Canada, where it is defined by the Detroit River, is crossed by five important railroads which, with their connections, form as many trunk lines from New York, the New England States and Eastern Canada to Chicago and the West. These roads as popularly known are the Michigan Central, the Wabash, the Grand Trunk system, the Pere Marquette and the Canadian Pacific.

The crossing of the swift current of the Detroit River, at the "City of the Straits," has been accomplished for many years, in summer and in winter, by powerful transfer steamers, operated by the various railroads. These ferry-boats are of such size that, from the station switching dock, any one of the ten will take on its broad deck an entire "limited" train, or half of a heavy freight train, and in fifteen minutes dock on the other side. The operation of cutting a limited express into sections, switching them on the boat, the ferry across the river, the second switching and connecting up of the sections, and pulling the train into the station consumes from thirty to forty minutes, and is a serious handicap to fast through passenger service between the East and the West. The delay and heavy expense of maintaining the ferries, especially in winter, when the ice floes frequently are decided barriers to navigation, have always been severe burdens on the railroads; and of late years the freight traffic crossing the border, to and from the Eastern States, having grown to enormous proportions, the ferry link is more than ever inadequate.

But the traveller who now finds the train ferry across the busy river, which looks so peaceful and blue, a pleasant incident in travel between Chicago and New York, will some day not far away experience very different sensations. When one of the greatest engineering feats of the decade is accomplished his train, running intact, will follow an unbroken line of track across the border. It will dip down deep in the earth, far below the bed of the river, and rise to the surface of another country in seven or eight minutes.

While this saving in time will be of some value to the fast express schedules, the real and great benefit to the railroads and the public will be in expediting the freight traffic between the West and the East. The ferry system at best is slow and cumbersome to the freight service, and delay often amounts to five hours. Even for solid trains of dressed beef, live stock and other perishables through to the seaboard, from two to three hours' time elapses before the train gets under way again. With the tunnel there will be less than an hour's delay.

Standing as the epitome of the Michigan Central's spirit of twentieth century progress, the tunnel under the Detroit River will come as the culmination of Henry B. Ledyard's successful administration of the affairs of the great system. For many years, almost from the time of his elevation to the presidency of the

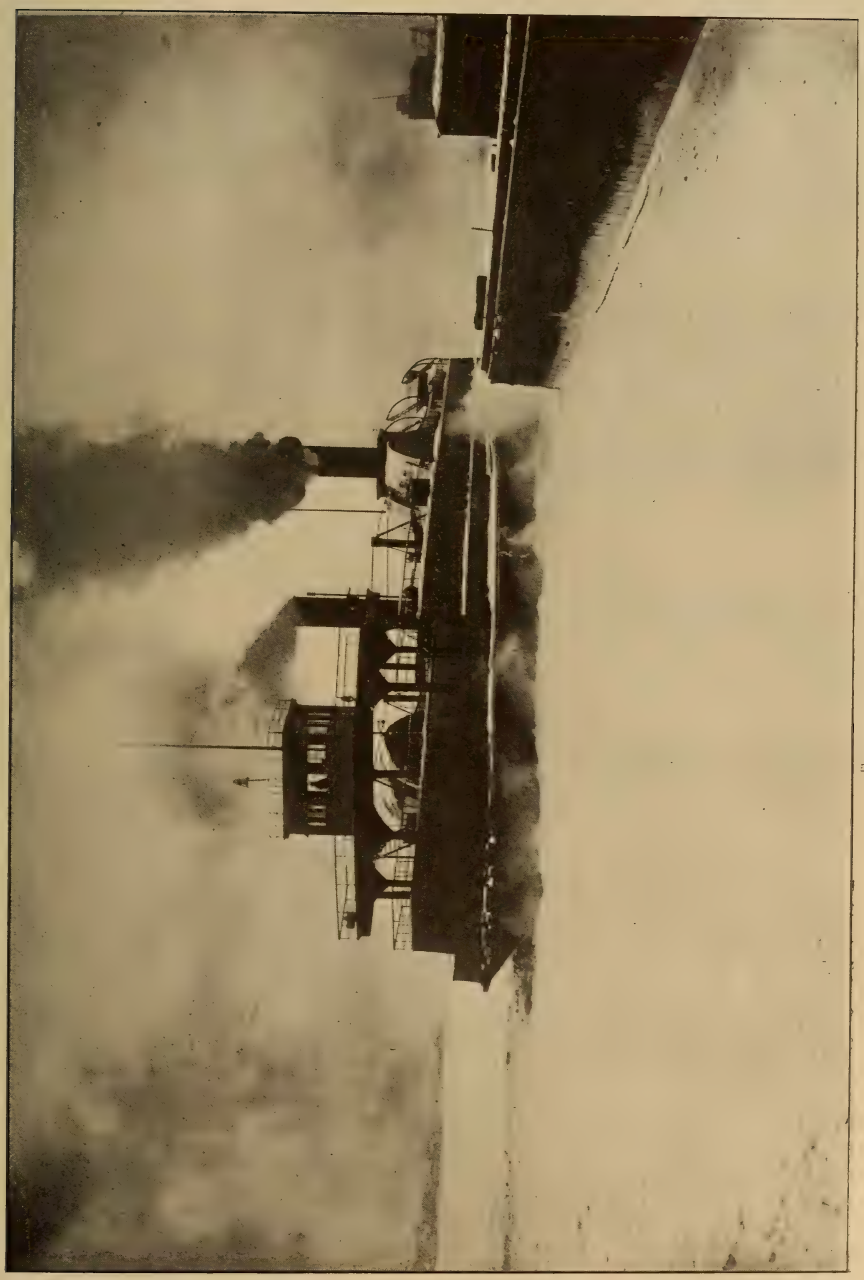
A TRAIN FERRY BOAT AT THE DOCK

road in 1883, Mr. Ledyard has regarded the break in the continuity of the double-tracked lines as a serious obstacle to regular and efficient service to the public. During these years, while watching the development of traffic, on the Central system alone, amounting to fifteen million tons in 1906, he has studied the problem of fusing the lines stretching through the province of Ontario to the East, and from Detroit away to the West.

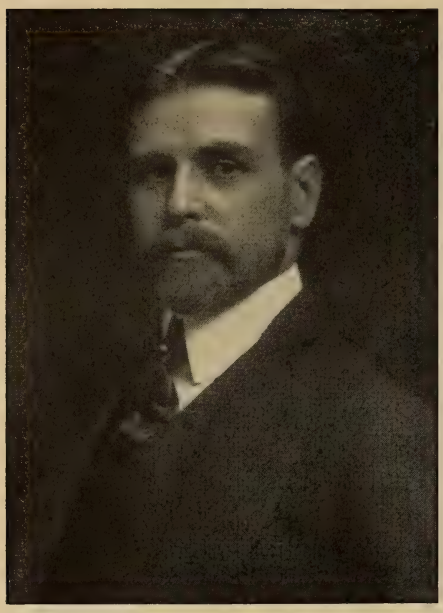
The problem was decidedly perplexing, and although for several years a bridge was considered the most feasible, the structure came no nearer realization than facts and figures and plans on paper. The objections raised by the vessel interests of the Great Lakes were sufficient to block the necessary legislation; and, furthermore, the railroads could not agree on a location for a bridge that would be convenient for them all.

Finally, when it became evident that the interests of Michigan Central were being jeopardized by the delay, Mr. Ledyard took up the project alone and, through his efforts, his board of directors authorized the construction of a tunnel under the Detroit River, and also granted the proper organization to carry out the great undertaking.

The construction of the Detroit tunnel line from Windsor, Ontario, to West Detroit yard, Michigan, including the electrification thereof, is placed in charge of an advisory board of engineers consisting of William J. Wilgus, chairman, vice-president of the N. Y. C. & H. R. R. R., who formerly had charge of the regeneration of the physical condition of that company for heavy motive power, and who now has charge of the improvements surrounding New York City in what is known as the electrification zone, including all lines between Grand Central Station, Peekskill and White Plains. H. A. Carson, second mem-



A TRAIN FERRY BOAT IN THE ICE



W. J. WILGUS
Chairman Board of Advisory Engineers

ber of the board, is consulting engineer, and is chief engineer of the Boston Transit Commission, in which capacity he has built practically all the subways in Boston. The final member, W. S. Kinnear, chief engineer of the Detroit River Tunnel Company, is in direct charge of construction, reporting to H. B. Ledyard, chairman of the board of directors, on executive and financial matters, and to the advisory board of engineers as to plans, specifications and methods of doing the work.

The work of designing a tunnel such as this is not the work of a moment. Months and months have been spent in making plans. Many of them were thrown away, discarded as useless, and new ones made, only to be thrown away, in turn. Meanwhile, test holes were being sunk at short intervals across the bed of the river and down to bed-rock, complete records being kept of the strata formations. With all the conditions known and figures and estimates made, the final plans were decided on in the summer of 1906. The plans provide for a "double-barreled" tunnel of steel and concrete, through which trains will be operated by electricity. While the entire cost of the undertaking is being borne by the Michigan Central, the other roads will operate through the tunnel by paying rental on a basis to be arranged later. The contract for the construction of the tunnel was let in the early summer of 1906 to Butler Bros.-Hoff Company, of New York, who took up the work at once, and it is being pushed with vigor, so that the tunnel will be completed and opened for traffic in the early summer of 1909.

The magnitude of the enterprise alone is worthy of note, but the novel method of construction, which is one of the most striking pieces of engineering of the present day, and the daring and skill of the engineers, mark the gigantic undertaking as one of great importance and of interest throughout the country. The Michigan Central tunnel is different from all other tunnels, and the construction is an entire departure from the methods used in previous tunnel work. None of the experience gained from drilling the rock may be used; none of the experience that came from the shield-driven bores of the Pennsylvania Railroad under the North and East Rivers, in New York, or the Grand Trunk tunnel under the St. Clair River at Port Huron is of avail. For many months problems of perplexing difficulties will be worked out to practical solutions by the board of engineers in charge of the work, and Benjamin Douglass, engineer in charge of construction, will carry them out. To these men will fall the laurels of success—the triumphant achievement of a remarkable engineering feat.

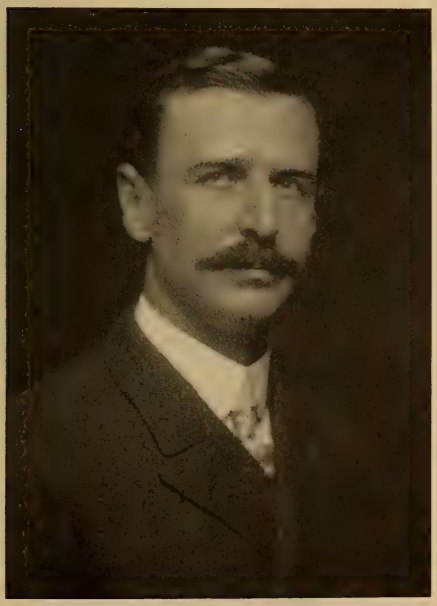
In the novel methods employed men will not be compelled to labour under the high pressure required in the shield-driven tunnels, where workmen are frequently overcome by the pressure of air, which is necessary in the shields to prevent the inrush

of water from above. There the air pressure must be slightly greater than the pressure of water on the bottom of the river, and the strongest men can labour only three hours at a time in the pressure of three atmospheres, and sometimes as high as 50 pounds to the square inch. No men will work below the bed of the river until the great tubes are in place. Then, and only then, will they enter the steel tubes to do their work. Until this part of the undertaking is completed very much of the work will be done in the open air, above the surface of the river; but even with the freedom of light and air, there are adverse conditions requiring constant vigilance of the engineer and his assistants.

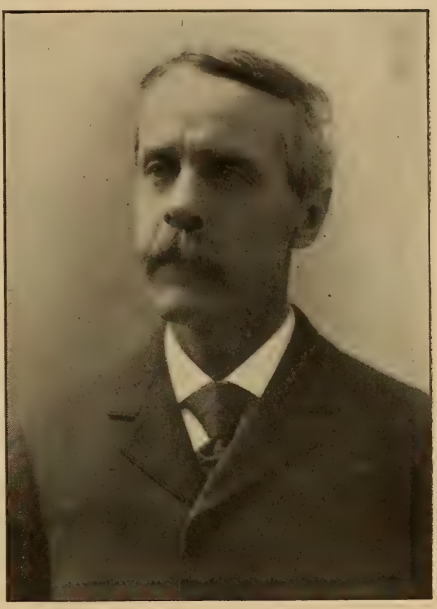
To understand clearly the marked difference in the new tunnels, let us consider first the construction of the main or subaqueous section, the portion under the river, which is decidedly the most interesting feature of the enterprise.

The river along the water-front of Detroit is about one-half of a mile wide, and the section of the tunnel under the stream will be 2,622 feet long. The depth of the river varies from 20 to 48 feet, and the current is swift. Instead of the tunnel being bored through rock and clay and slimy sand many feet below the river bed, a wide and deep trench is being excavated, and the great steel tubes, now being built up in sections at the shipyard of the Great Lakes Engineering Company, will be lowered into the trench. The problems to overcome, the difficulties arising from the intricate processes of lowering and adjusting the huge sections in exactly the right position, the joining of the sections so as to be absolutely watertight, and the covering of the tubes with concrete, are the principal features of the undertaking, and when at last it is completed a new chapter in tunnel building will have been written for filing away in the archives of the engineering world.

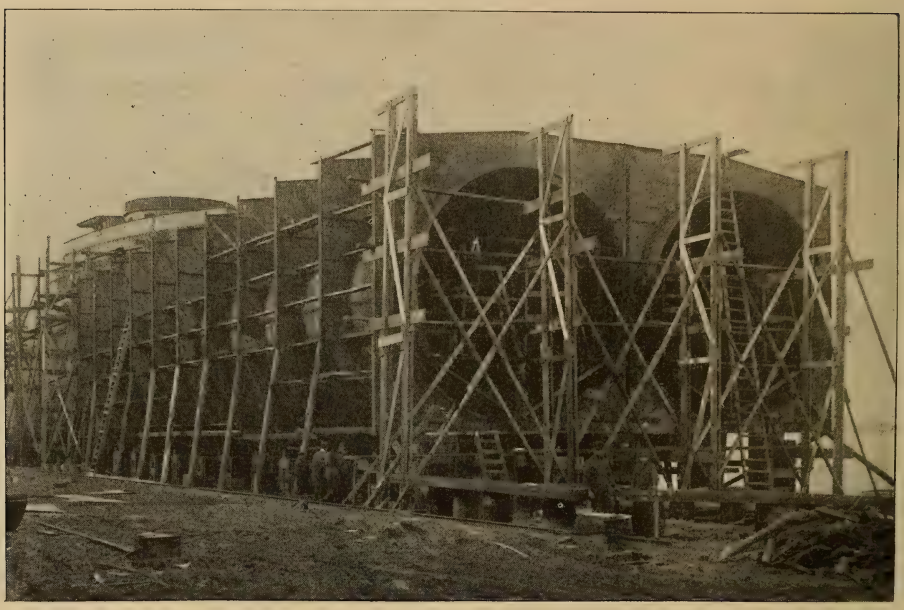
The credit for this notable engineering scheme belongs to Mr. Wilgus, who conceived the idea of the



W. S. KINNEAR
Chief Engineer, Detroit River Tunnel Company



HOWARD ADAMS CARSON
Consulting Engineer, Advisory Board of Engineers



A PAIR OF TUNNEL TUBES READY FOR FLOATING

trench and tubes method of tunnel construction. It was he who worked out the practical details of the plan, and who devised the ways and means by which the problems are to be carried out. It is a happy augury of the success of the enterprise that the other members of the advisory board not only agreed as to the feasibility of the methods proposed, but also strongly advised their adoption, and now are the strongest advocates of the system.

Huge dredges of the dipper type are now busily engaged in digging the trench to the depth of 45 feet below the bed of the river. The bottom will be dug out still further by the use of clam-shell dredges, and will be 40 feet wide, thousands of cubic yards of earth being removed. As the excavation goes on the dredges are followed by pile drivers, which drive piles down to the very bottom of the trench, so as to form a series of firm supports for the huge tubes to rest upon while they are being adjusted and bolted in place.

Permission has been granted the Tunnel Company by both the United States and Canadian Governments to obstruct not to exceed 600 feet of the river at any one time. This limit will be occupied by scows, lighters and dredges, which are to be employed for lowering and anchoring the tubes and depositing concrete covering. During all these operations there will be little danger to the craft that ply on the river or the numerous liners and hundreds of freighters that pass through the river. Every safeguard will be provided to avoid accidents to the lake craft.

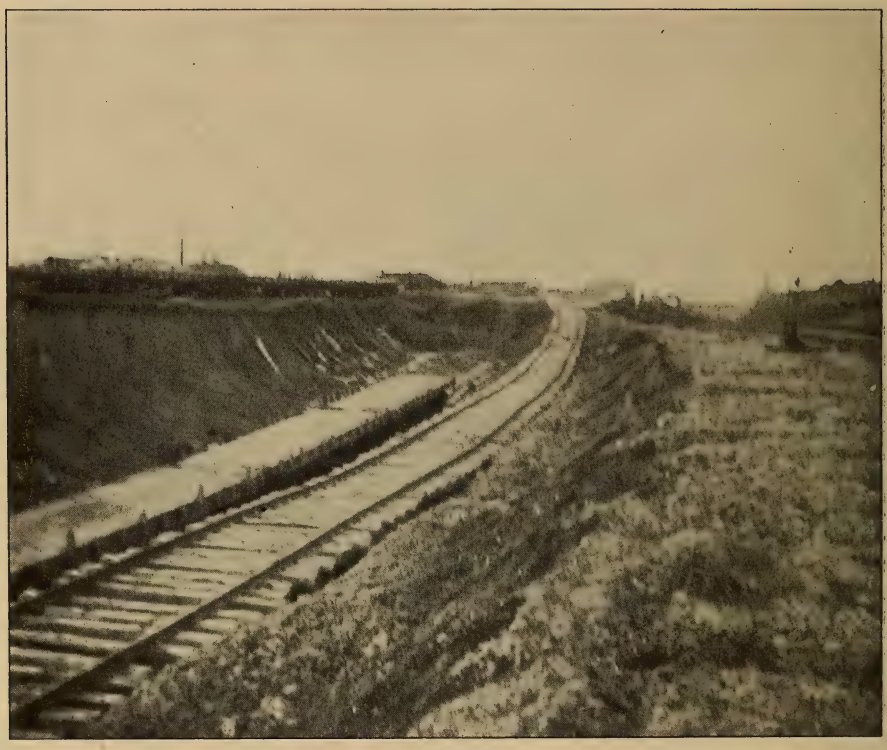
The building of the steel tubes is a task of the first magnitude. Made up from plates of steel, three-eighths of an inch thick, the sections are 23 feet in diameter and 260 feet long. At intervals of 11½ feet on the outside of the tubes there are transverse diaphragms which strengthen the tunnel and divide into sections the space to be filled with concrete. The sections are built on land at the engineering works, 48 miles away, and the means employed to convey the heavy mass of steel to the tunnel are both simple and ingenious. As the sections are required in the tunnel

work, they are riveted together in pairs, the ends are "plugged" and made watertight, then they are launched into the river, and by tugs and heavy hawsers are towed down stream to where the gangs of men are ready to sink them in place. The scows that are used in lowering the heavy steel tubes are securely anchored and as immobile as it is possible to make them in the swift current, with the surface of the river constantly churned into swells by many passing steamers. To this end, 25-ton blocks of concrete are used. Four of these blocks, one for each scow, are cast in the river upstream from the scows and attached by chains and hawsers.

When the floating tubes are placed exactly over their intended resting place and everything is ready for the lowering, water is admitted to the tubes and, as they gradually fill, they settle by the law of gravitation until they rest on the firm supports of piling. In this operation the highest engineering skill is called into use, so that the great mass of steel will rest exactly in its proper place, with the utmost precision, so that the tubes will be in alignment with the sections previously put in place, and also that each of the external diaphragms will rest on the beam intended for it. As an aid in this operation, each pair of tubes is provided with a detachable upright at each end, firmly braced to the tube, and of sufficient length to indicate the position of the tube when sinking. These uprights will serve, after the sections of tube are sunk, in the adjustment of their position laterally, and, therefore, extend above the water about 10 feet when the tubes are in place.

After the tubes are adjusted laterally to their correct position, there is much fine work for divers to do, the work that means so much. Upon them devolves the responsibility of the joints which connect the great

SHAFT ON THE DETROIT APPROACH TUNNEL UNDER LAFAYETTE AVENUE



PORTION OF CUT ON CANADIAN SIDE. THE PORTAL WILL BE ABOUT THE PLACE WHERE THE TRACK DROPS. THE RAILS WILL BE 57 FEET BELOW THE SURFACE

twin tubes. Working way down in the depths of the open trench, with nearly 80 feet of water over them, the divers crawl along under the tubes and examine carefully all bearings of the diaphragms on the beams of the piling and, where needed, insert shim plates of the proper thickness, to produce exact bearings. The next operation is to bolt the huge sections together, so that the joints will be absolutely watertight, and the accomplishment of this reflects the greatest skill.

Each tube, when built, is provided with a "sleeve" at one end, which can be slipped over the end of the tube previously sunk. This sleeve is made with a flange that is bolted to a corresponding flange on the adjoining tube, a rubber gasket being placed between them. A similar gasket is fitted in the inner end of the sleeve bearing up against the edge of the other tube. With the sleeve and gaskets in place, the divers bolt up the flanges, and in this operation the gaskets are squeezed together between the ends of the tubes, forming a tight joint. A space of 3 by 18 inches is thus formed around the tubes at the end of the joint, and this is filled with a grout of cement. To insure the space being entirely filled, the sleeve is provided, on the top, with two small flexible pipes leading to the cement scow above. The joints are first tested to ascertain whether they are tight, and this is done by pumping out the water in the space and continuing until no more comes. When the joints are all tight, the cement grout is forced into the space through one pipe until it comes out of the other, which is evidence that the space is completely filled.

The tubes, now resting on secure

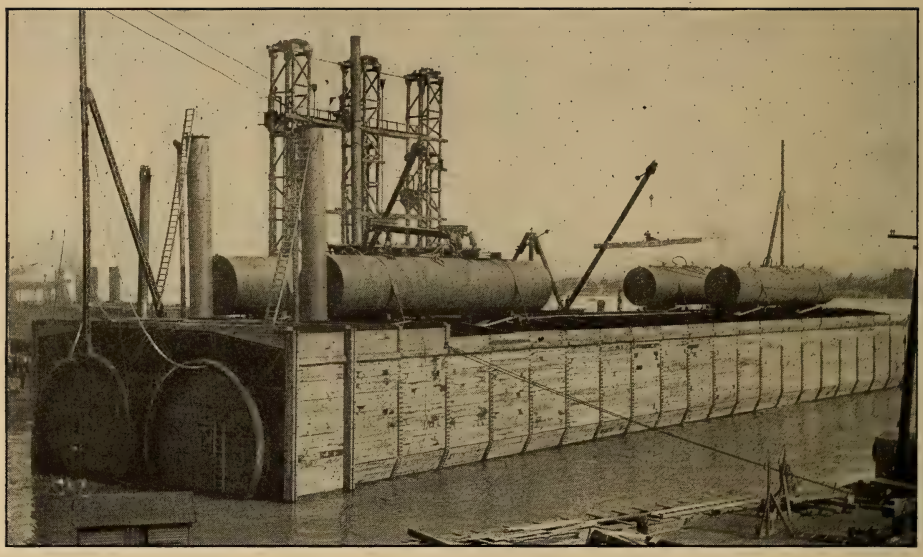
foundations and bolted together with perfectly tight joints, are still far from complete. They must have a thick covering of concrete to protect them from the destructive effects of water, and also to make them more sound and rigid. In this process gravel is first deposited over the bottom of the trench to a depth of 2 feet, to make a proper bed for the concrete, which, upon hardening, encompasses the foundation, piling, the tubes, diaphragms and sleeves in a solid mass of stone.

To keep the concrete in proper form above the tubes while solidifying, sheathings of 3-inch oak planking are built up vertically, attached to the diaphragms and forming sides of trough carrying the tubes. These are carried fully 5 feet above the tops of the tubes.

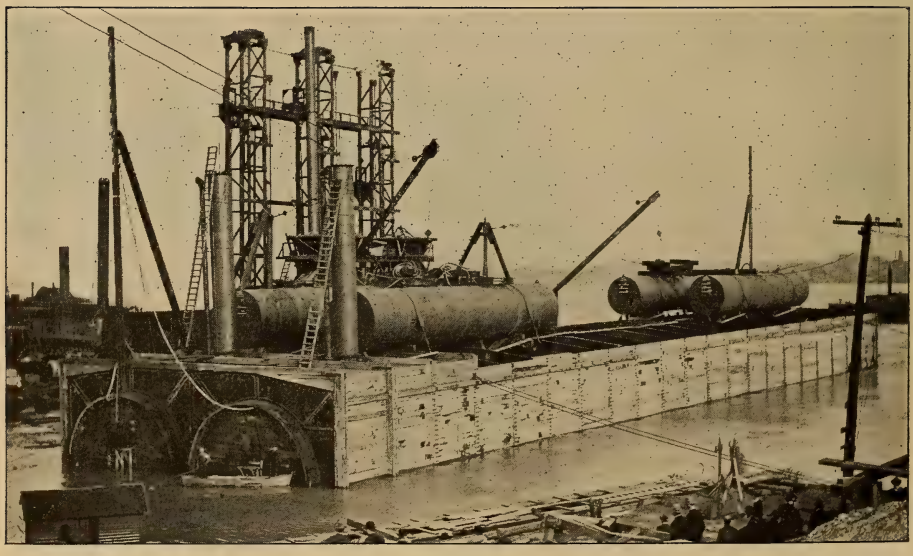
The trough thus formed is supported on the outside by a filling of sand and gravel. The concrete is mixed on the scows and poured into chutes that deposit it within a few inches of where it is needed. As the work goes on, the concrete is chuted down between the tubes and spread over the bottom of the trench in one solid mass, and is carried up over the tops of the tubes to a thickness of about 5 feet. The open trench back of this huge mass of stone is then filled with clay and covered with loose stones. After a time when the concrete is solid, and the bulkheads in the outer ends of the tubes that were put in at the engineering works still being in place, the water inside the tubes is pumped out by steam pumps at the shore shaft, thus completing the outside and under-water work.

So far as we have gone we have seen only the multiple operation of constructing the outer shells and their protective coverings. We have had no glimpse of the tunnel tubes them-

DIGGING THE LONG APPROACH ON THE CANADIAN SIDE

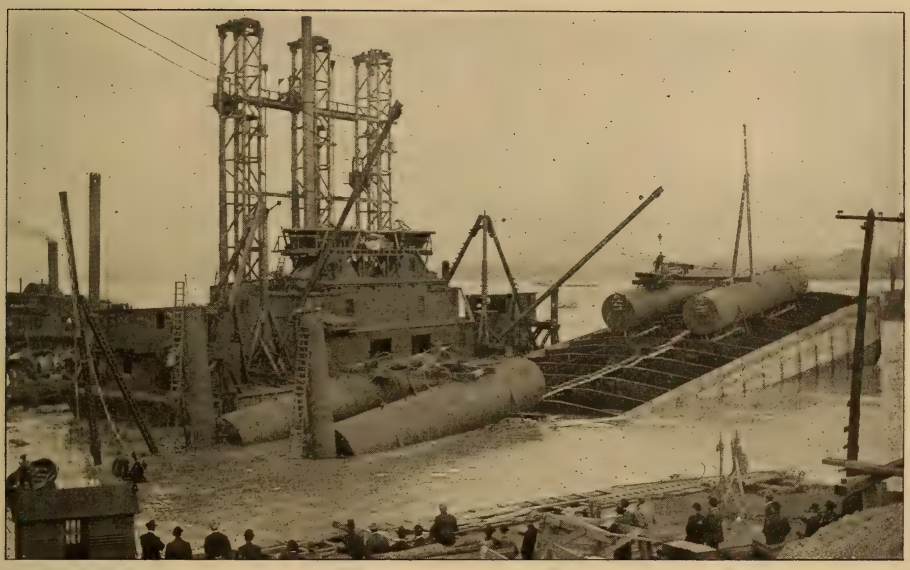


SINKING TUNNEL TUBES. 1.04 P.M., OCTOBER 1, 1907



SINKING TUNNEL TUBES. 3.23 P.M., OCTOBER 1, 1907

Courtesy of *Engineering News.*



SINKING TUNNEL TUBES. 4.00 P.M., OCTOBER 1, 1907

SINKING TUNNEL TUBES. 4.35 P.M., OCTOBER 1, 1907

Courtesy of *Engineering News*.

selves, because none of the actual tunnel work on this section had yet been done. The steel tubes that were built and lowered so carefully way below the bed of the river are, in fact, only the shields within which the tunnel tubes are formed. The steel shields are the water-proofing of the tunnel tubes within, and the concrete covering is but the foundation and encompassing mass of stone to give an additional measure of rigidity and strength to the tunnel.

The tunnels proper are the 20-inch thick rings of concrete built within the rounded forms of the steel tubes, and are of sufficient strength to meet all stress and strains of the heaviest trains, of 2,000 tons, passing through the tunnel.

On each side of the lower section of the tubes there are benches of concrete 4 feet high and 2½ feet wide at the top, to s rve as passageways and places of refuge for the track men. When completed, there will be a clear head of 18 feet from the top of the rails to the centre of the arch, and 16 feet 6 inches wide across the centre line. In all, there will be ten of the 260-feet sections required to connect the dock lines of the American and Canadian shores. Four of these sections will be on the level. From a point about 1,000 feet from the Detroit line the tunnel has a 2 per cent. grade extending to the westerly summit, which will be where the railroad tracks cross Fifteenth street on the way to the station yards. Near the Canadian shore the tunnel rises on a 1½ per cent. grade to the easterly summit in Windsor, a mile from the river. The lesser grade on the eastern portion of the tunnel is due to the greater traffic eastward of high-class freight. Trains are made up in Chicago to run through to the Eastern terminal without break and, being as heavy as the maximum power of the locomotives to haul them, the eastern grade of the tunnel is being made as easy as possible under the conditions.

The construction of the approach tunnels is proceeding on plans well founded by engineering practice, and this part of the work is a large undertaking of itself. To have a correct idea of this it may be well to note that the length of the approaches is 5,338 feet, which, with the under-river section, makes a total length of 7,960 feet from portal to portal, a distance of more than one and a half miles. The open cuts are 4,840 feet long, giving the tunnel and approaches a total length of 12,800 feet, or nearly two and a half miles. This distance will not be exactly straight, as there will be two slight curves, one on each side of and near the river. They will be long, easy curves, with an aggreate length of 2,600 feet, with two degrees as the maximum of curvature.

In constructing the approach tunnels, two shafts were sunk on each side of the river, one on each shore, and others about half way between the first shafts and the portals. In this way a number of excavating gangs may be worked at the same time by digging in both directions. The operations are going on steadily, and beside the excavating, concrete gangs are mixing and building up the walls of the bores with concrete. These walls are 4 feet thick, arched overhead, and covered with a water-proofing of layers of tar, pitch and felt, which, in turn, is protected from injury by 4 inches of cement and brick. The shafts near the river banks are to be permanent, and are lined with strong double-walls of concrete. They will serve to ventilate the tunnel and as outlets for the drainage pipes, as well as an exit in case of accident in the tunnel.

On the Canadian side, steam shovels are now working in the cut, digging out many hundred cubic yards of earth every day, yet still there is much to be removed before the proper depth is reached for the portal. The portals of the tunnel will be of concrete, handsomely decorated and surmounted with a cornice and balustrade. The retaining walls of the

open cuts rise to the height of the portal face and continue out for about half the length of the cuts, reducing in height as the tracks come to the surface. Stairs will be built in at both sides leading down from the top of the retaining walls to the level of the benches of the tunnel. The retaining walls will be built out for 1,090 feet from the portal on the Detroit side and 800 feet on the Windsor side. The walls will have a 4-foot footing course of concrete, and at the top will be 29 feet apart, which allows 13 feet centres for the tracks. A gas pipe fence will surmount the coping. Drainage is provided for by a line of 6-inch tile laid under the paved gutters along the wall, and drains through the walls will carry off water collecting behind the walls. The drains empty into sumps of 20,000 gallons capacity, located outside the portals.

From the plans and descriptions given, we see that concrete is the main factor in the construction of this important tunnel, supplementing most effectually block stone and brick, which were the principal materials used in tunnel work to a recent date. Immense quantities of the ingredients that go to make concrete have been contracted for, and it is of interest to know that 300,000 barrels of Portland cement, 250,000 tons of screened gravel and nearly a million barrels of sand will be required. The sand is supplied by a large sand-sucker that secures the desired quality, and quantity, too, at the mouth of Black River, at Port Huron, 60 miles distant, and it will take two years' constant sucking and lightering to fill the contract.

Electricity will be the motive power used to haul the trains through the tunnel, and the eight locomotives required will be the most powerful that electrical science will have evolved in 1909. The electric current, amounting to about 6,000 H. P., will be furnished under contract by the Detroit Edison Company. Only a small converting station will be necessary to convert the alternating current from the feed wires to a direct current for the locomotives.

The tunnel inside will be of the light concrete finish and brilliantly illuminated by countless electric lamps. It will be clean and well ventilated, and entirely free from the deadly coal gases that fill tunnels operated by steam locomotives. There will be no grim record of death in the Michigan Central tunnel.

It is estimated that the tunnel will cost at least $8,000,000, but this expenditure is considered moderate in view of the saving effected in operating expenses over the present means of moving the enormous traffic across the border.

THE PRACTICAL SIGNIFICANCE OF THE CARNOT CYCLE

By Joseph H. Hart, Ph. D.

In the numerous attempts to attain maximum efficiency in the conversion of heat into work, practieal engineers are beginning to realize the importance of keeping in mind a clear conception of the fundamental principles underlying their efforts. Too often the abstract elements of the problem are given such a prominent place in discussions of the question that the practical portions, those which the engineer requires for his immediate needs, are obscured. Dr. Hart has endeavored to place the practical side of the subject in such clear language that it may be used in connection with engine design, freed from unnecessary verbiage, and rendered available for immediate service.—THE EDITOR.

EVERY engineer is more or less familiar with the form of the Carnot cycle, but very few understand its full significance and its relation to the ordinary steam cycle. It is fairly well known that at least one engine, the Diesel motor, follows this cycle very closely, but the reason why this series of changes allows a so much greater efficiency than can be obtained by the changes in the ordinary engine and the reason why the theoretically greatest possible efficiency obtainable by any engine is limited through a study of this cycle, are things which are more or less hazy in the minds of most engineers. This is due to the fact that the majority of engineering text-books treat the subject inadequately, and from a physicist's rather than an engineer's point of view. Also, to most engineers the subject appears to be purely theoretical, and very little emphasis is put on its very close relationship to purely practical developments. The result is, that the conclusions which are obtained seem dogmatic and lose most of their strong vital significance.

The fact is, however, that the study of heat and heat changes has become simply a study in molecular mechanics, as the name thermodynamics implies, and Carnot's cycle and the results obtained from it are simply the statement of a simple mechanical law, which every engineer would easily understand and regard as almost axiomatic if developed under ordinary mechanical conditions. The second law of thermodynamics, developed from a study of the Carnot cycle, is just as vital a law in ordinary mechanics as the law of the conservation of energy, but it does not become prominent in ordinary work because the conditions necessary for its consideration and utilization seldom, if ever, occur under existing mass relations.

Now in order to understand the Carnot cycle and its significance, we must understand existing heat conditions from a mechanical point of view. Heat is known to be the mechanical energy of the molecules. In a gas the molecules are believed to be free from each other and flying rapidly around in all directions and colliding and recolliding with one another and with the walls of the containing vessel. The pressure of a gas is due to the multitudinous impacts of this horde of molecules. The walls of the confining vessel also consist of molecules, not possessing such freedom of motion, however, but also containing a great deal of mechanical energy. At this point in the visualization of existing conditions the ordinary engineer stops. It seems too complex a condition and with too little practical application for further extension. He may know

that the piston in a steam engine moves under this bombardment in precisely the way a piece of armour plate on a wagon would move if subjected to a continuous hail from a number of rapid-fire guns, but what happens to the molecules after such bombardment and the individual energy losses involved in each molecule appear to be unnecessary knowledge in his profession.

If we attempt to go far into this realm of the kinetic theory of gases and treat the subject in the ordinary mathematical manner usual in such cases, this is absolutely true, but a simplification to a consideration of the behaviour of a single molecule and its energy changes under various external changes is of the greatest benefit toward a realization and understanding of many important relations in power production and utilization. In this case, the molecule is regarded as a not necessarily known fractional part of a pound of the working substance, but always the same proportional amount of the same working substance, and the interrelations of the molecules and their interchanges of energy can be disregarded with very little error in most of the practical developments. The real significance of the Carnot cycle and its practical application can be easily and completely understood through a consideration of the behaviour of a single molecule during these transformations.

Let us now consider the Carnot cycle as ordinarily understood. It consists of a theoretical series of changes in the pressure, volume and temperature of a gas or of any quantity of the working substance, such that the original condition of the working substance is again attained at the end of the cycle, and the process may thus be repeated indefinitely. The series of changes consist of two isothermal and two adiabatic changes in the pressure and volume of a gas, each of these two changes consisting of a compression and a rarefaction, and the isothermal and adiabatic changes alternating with each other in any manner that seems desirable. In the ordinary treatment of the subject imaginary non-conducting cylinders are considered, a hot reservoir, cold reservoir, and non-conducting base are supplied, and a series of changes is gone through which shows actual relations, but which complicate and obscure the issue at hand.

Now the Carnot cycle consists primarily of an expansion and a compression of a gas so that available work is attained and the original condition of the gas or working substance also reached, so that the process can be repeated any number of times and any given amount of work obtained. Now work is force times distance, or in the case of a gas it can be pressure times change in volume; therefore, the only way in which work can be obtained from a gas by a simple expansion followed by a compression to the original volume, is by having the expanding pressure much greater than the compressing pressure. This is attained by keeping the gas hot during expansion and keeping the gas cold during compression, since for a given volume and weight of a gas or working substance the pressure is directly proportional to the absolute temperature. This is the basis of all practical transformations of heat into work. In some cases the return compression is impracticable or uneconomic, but is theoretically possible, and all the transformations differ only in the duration in the cycle of the high and low temperature and the methods by which the change from one temperature to the other is accomplished.

To see this more clearly, take the ordinary steam engine cycles. The expansion curve is a constant pressure curve, with change in quantity of steam producing the change in volume up to the point of cut-off, and after this the expansion curve is known as a saturation curve, which is neither an isothermal or an adia-

batic, but generally falls between the two on a pressure volume chart or indicator card. The compression occurs by removing the heat by means of the condenser, so that there is no opposing pressure to the diminution in volume, and the change back to the high pressure occurs in the boiler by raising the temperature of the steam and water and by the addition in this limited volume of additional steam made from the water. Thus the ordinary steam cycle consists of two expansions, followed by two compressions, the latter more or less disguised from ordinary compressions. All transformations of heat into work in which a gas or vapour is used as the working substance consist of the two expansions, followed by the two compressions. Only in exceptional cases do all of these operations occur in the cylinder of the engine, so that the ordinary indicator card is a measure only of work done and not at all of heat consumption. In the gas engine only one compression occurs, and the exhaust gas is not reconverted, apparently, into fuel, but new material supplied. The cycle is completed externally here, however, by forces of nature producing chemical reactions, and the same series of events may be traced out.

All transformations of heat into available work, therefore, consist of an expansion of a gas or vapour at a high pressure and temperature, followed by a change to a low pressure and temperature. Then comes the compression at this low pressure and temperature, followed by a change to a high pressure and temperature. The two changes take the form of a more or less disguised expansion and compression. Now the Carnot cycle is a typical example of such a series. The isothermal expansion at a high pressure and temperature is followed by an adiabatic expansion, which rapidly lowers the temperature and pressure of the gas. Then the isothermal compression at this low temperature and pressure is followed by an adiabatic compression, which rapidly raises the temperature and pressure of the gas to their original values. The real significance of this series of changes and its theoretical importance is obtained only by a study of the exact nature of the changes themselves.

An isothermal expansion means an expansion in which the temperature of the gas or vapour does not change. The absolute temperature of a gas is directly proportional to the mean kinetic energy of the molecules; therefore, an isothermal expansion is one in which the mean kinetic energy of the molecules does not change. However, when a molecule hits a piston and causes it to move, it loses a portion of its kinetic energy. Therefore, in an isothermal expansion, this energy must be immediately resupplied to the molecules by the hot walls of the containing vessel, and thus every time a molecule hits the piston it hits with the maximum energy available, and every blow counts for the same amount and is dependent only on the temperature or average kinetic energy of the gas.

An adiabatic expansion is defined as one in which heat does not go into or out of the gas as such during the expansion. This means that the average kinetic energy or the temperature of the molecules can change only by doing work on the piston or by receiving kinetic energy from its motion and not from the heat or kinetic energy in the walls of the containing vessel. Therefore, in an adiabatic expansion, the molecules hit the piston once and lose a portion of their kinetic energy or temperature, which is not replaced. On the second blow they lose still more, and the kinetic energy of the molecules or their temperature, and, of course, their pressure, is thus reduced in the quickest and most efficient manner without any outside work whatever being required.

In the isothermal compression, the volume is reduced by hitting the molecules with the moving piston and

forcing them in. Every time a molecule hits the piston, moving in an opposite direction, it rebounds with more kinetic energy than it had before and, therefore, its temperature is higher. It loses this energy to the walls of the containing vessel before it hits the piston again; therefore, every blow on the molecules with the piston is given at the best possible advantage and the volume is reduced with the least possible amount of external work, if the molecules are kept at this lowest temperature.

The adiabatic compression also does its duty in the best possible manner. The molecules hit the moving piston and rebound with more energy. They do not lose this, and when they hit again they rebound with still more energy, and the average kinetic energy of the molecules or the temperature, and consequently the pressure of the gas, is increased to the original amount with a minimum amount of effort and absolutely no waste of energy.

Therefore, we have in a Carnot cycle an expansion in which the energy is utilized to its very best advantage and the blow of each molecule delivered with maximum effect. Then follows a change to a lower temperature and pressure with no external effort and accomplished most efficiently. This is followed by a compression in which each blow of the molecules counts for the least possible effect, and the least possible outside work is done at that temperature. Then comes the change back to the original point with least possible effort and no waste.

The expansion is carried out to its full limit with each molecule working at the maximum efficiency compatible with that temperature. The compression is carried out also to its full limit with each molecule working at the least disadvantage compatible with the lowest temperature attained in the cycle. The changes in temperature and pressure are brought about with a minimum amount of loss and neutralize each other absolutely, in theory. That is, in the adiabatic expansion, a certain amount of energy is taken from each molecule, and in the adiabatic compression the same amount of energy is given back to each molecule, in order to give it the same kinetic energy or temperature as before, and there are the same number of molecules or the same amount of working substance in each transformation. Therefore, this transformation is perfect theoretically, and there can be no series of changes in pressure and volume and temperature of a gas for the obtaining of work, which can be accomplished more efficiently. It is this particular property of the Carnot cycle which renders it important in practical work.

Now in the Carnot cycle the only changes which we need consider are the isothermal ones, since the adiabatic expansion and compression exactly neutralize each other, as far as work or heat is concerned. In the isothermal expansion each molecule has a certain amount of kinetic energy proportional to the absolute temperature, and as fast as it loses this to the piston it obtains it again from the source of heat or kinetic energy. In the isothermal compression each molecule has a certain amount of kinetic energy proportional to its absolute temperature, and it receives a proportional amount from the piston, which it immediately loses to the walls of the vessel or to the condenser. If the adiabatic expansion has used up all the energy of the molecules and thus reduced their temperature to absolute zero, the isothermal compression could be carried on at this temperature without doing any work at all and, in general, the work necessary here is always proportional to the absolute temperature at which it occurs. The efficiency of any work transformation is the ratio of the useful work to the total work. The total work is the total energy or heat put into the substance or the molecules in the isothermal expansion, and is pro-

portional to the absolute temperature at which this occurs. The available work is the difference between the work taken out and that put in, but each of these is proportional to the absolute temperature at which it occurs; therefore, the difference is proportional to the difference in absolute temperatures between the working substance in the two isothermal changes. Thus we arrive at the well-known statement that the best possible efficiency of any heat engine depends on the absolute temperature, and is equal to the difference between the initial and final absolute temperature of the working substance, divided by the initial absolute temperature.

These, then, are the results attained by a study of the Carnot cycle. It is theoretically the most perfect series of transformations for heat into work, and a formula for efficiency has been attained. Now the value of these two ideas in practical work has been grossly overestimated. In some cases, their significance and application have been misconstrued, and in others they have not been considered where they should have had first place. For instance, the acceptance of the idea that the Carnot cycle was the best led to attempts at its practical application, whereas a knowledge of its true significance would have shown its imperfections in practical work as well. The Diesel motor utilizes this cycle. The adiabatic expansion and compression theoretically balance, but their friction losses are cumulative. They may take such a large proportion of the stroke that to have any capacity at all would require an engine of abnormal size or pressure. The isothermal expansion always makes a jacket desirable, and an isothermal compression can seldom, if ever, be attained at the high speeds now found desirable. Also a working substance of high heat capacity cannot be used. The wonderfully high efficiency of the Diesel motor is not due to its rigid adherence to the Carnot cycle. It can be explained by a more complete elimination of heat losses and a higher controllable initial temperature than most engines, and hence a higher pressure. The Carnot cycle is superior to others possessing the same initial and final temperature only in the fact that more work, theoretically, can be obtained from a given quantity of heat. No attention has been given to necessary quantity of working substance or necessary losses incident to the production of this cycle. In general, for a given size cylinder, the ordinary steam engine cycle produces a much greater quantity of work, although it utilizes a larger proportionate quantity of heat. However, this consumption is only one factor out of many that must be considered in practical power production, and a satisfactory solution to this problem has not, as yet, been obtained.

Now, in regard to the efficiency idea, as developed from the Carnot cycle, it can be said, too, that this has been thoroughly misunderstood. Most engineers believe that it is their duty to develop engines with higher and higher initial temperatures and as low a final temperature as possible, to satisfy these requirements of the Carnot cycle. Now the facts of the case are these. The molecules of coal possess, like all known bodies, a certain amount of kinetic energy, dependent on their absolute temperature under ordinary conditions. When the coal is burnt, a certain amount of kinetic energy, which has been previously concealed, is released, and increases the kinetic energy of the molecules. Only this energy which is set free can ever be utilized, and the other can never be touched. When a pail of water is raised 100 feet above a lake 400 feet deep, it possesses potential energy, of course, due to its being 500 feet above the ground. Only 20 per cent. of its energy, however, is available, and only the work put into it in raising it 100 feet can ever be obtained again. If it is raised 200 feet, 33 per cent. of

its energy can be obtained, but in no case can more be obtained than was put into it to raise it above the common level. It is the same way in regard to heat. A pound of coal gives out a certain number of calories or a certain amount of kinetic energy when consumed. This will raise the temperature of a pound of the working substance a fixed amount. It will raise half a pound of the substance twice as much, and so on. The advantage of high temperature is easily understood. A pail of water raised higher and higher has its energy more and more concentrated per pound of water. Temperature raised higher and higher means that the energy is more concentrated per molecule or per pound of working substance. Of course, in both cases, higher and higher efficiencies develop, as far as utilization of total energy is concerned, but only the energy put in can ever be utilized. The apparent advantage, in practice, of high temperatures is due to the concentration of the energy and the diminution in size of plants, with the corresponding saving of heat wastes and other losses. The second law of thermodynamics is only the statement that the common energy of the universe, visible in its absolute temperature, can never be utilized.

The Carnot cycle has led to a number of other developments in the heat theory, and these are of the greatest importance in engine theory and design, since they lead, in time, to the conception of entropy, and have great influence in the selection of the working substance. Enough has been said, however, to show the real significance of the Carnot cycle in practical work, and the remainder is more especially of interest to specialists in this line.

ELECTRIC POWER IN COAL MINING

IN the course of the development of coal mining it has been the aim of the mechanical engineer to substitute, as far as possible, various kinds of mechanical appliances in the place of human and animal labour. The principal incentive to Watt and his predecessors in the perfection of the steam engine was to provide a means for removing water from the pits of collieries and other mines, and the whole course of the evolution of the steam engine shows the influence of this environment. The beam was adopted in the first engine simply because it gave opportunity to place the cylinder upon a solid foundation close to the pit, and furnish a connection which could reach over the mouth of the shaft and operate the long pump-rod which extended down to the bottom. When, later on, the engine was applied to produce rotary motion, the connecting-rod and crank were substituted for the pump-rod and pumping cylinders, and thus the beam engine was an outgrowth of the pumping engine as originally designed for the coal pits of Newcastle and the copper mines of Cornwall.

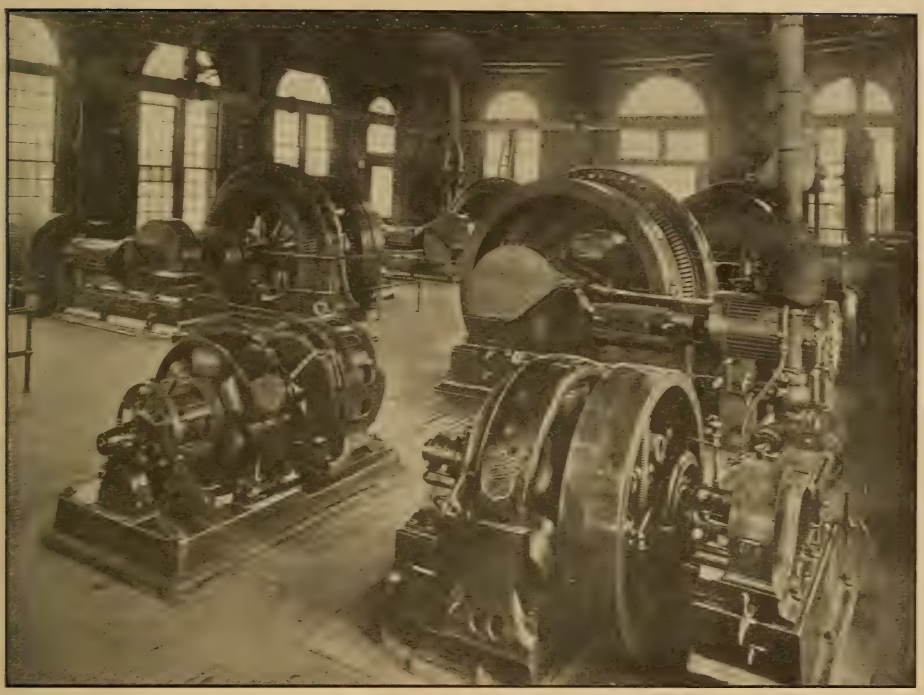
A similar development has now arisen in connection with the application of electric power to mining machinery, but in the reverse direction.

The electric motor is essentially a rotary machine, that is, it gives directly a rotative motion of comparatively high speed. Since the ease and convenience afforded by the electric current for the distribution of power in mines is causing it to be widely adopted, there has followed a natural tendency to adapt the operative machinery in mining operations to continuous rotative movements in the place of the reciprocating motions formerly employed.

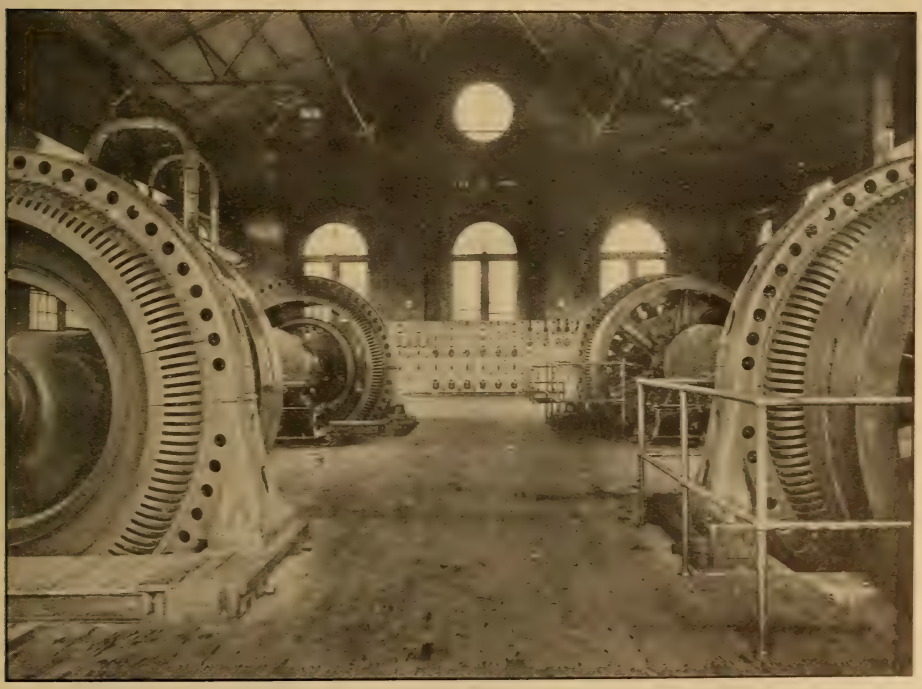
In the electric generating stations connected with coal mines the question of the type of power generating machinery is not altogether settled. In some cases the reciprocating steam engine, with its direct-connected electric-generating set, continues to find favour. In others it has been found advisable to install steam-turbine sets, and in certain locations the turbine possesses important advantages, especially when space is limited and good foundations are difficult of construction. When, as is often the case with coal mining districts, there are in the vicinity of the mines extensive iron works, with their blast furnaces and coke ovens, it has been found advantageous to install gas power plants, using the waste gases from the furnaces and ovens as fuel. The choice of motive power must naturally be determined by local conditions, but there is, in the majority of cases, a tendency at present to convert the power, by whatever means generated, into electricity for transmission, distribution and application to the various purposes for which power is required in the mine.

PUMPING

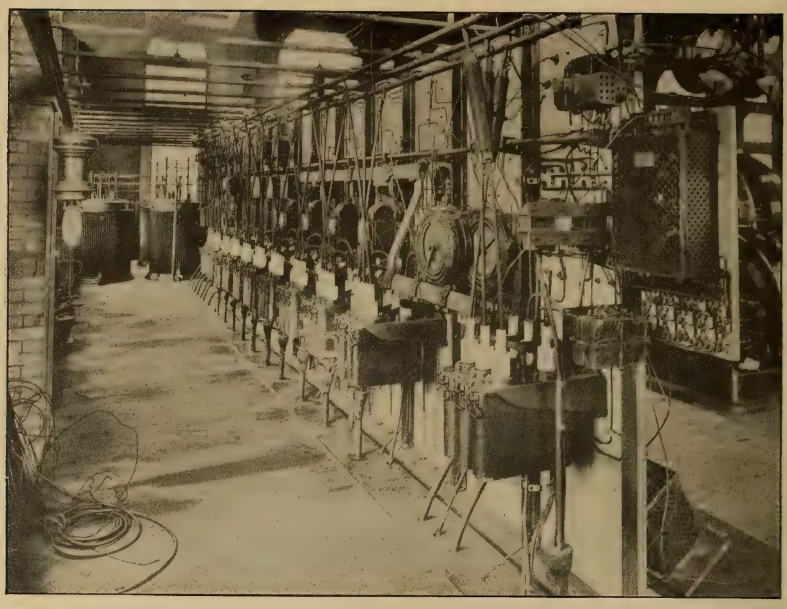
The adaptation of machinery to the rotation of dynamos has also made considerable progress at the pumping stations of a mine. From



GENERAL VIEW IN THE MAIN POWER HOUSE OF THE YORK RUN PLANT OF THE H. C. FRICK COKE COMPANY

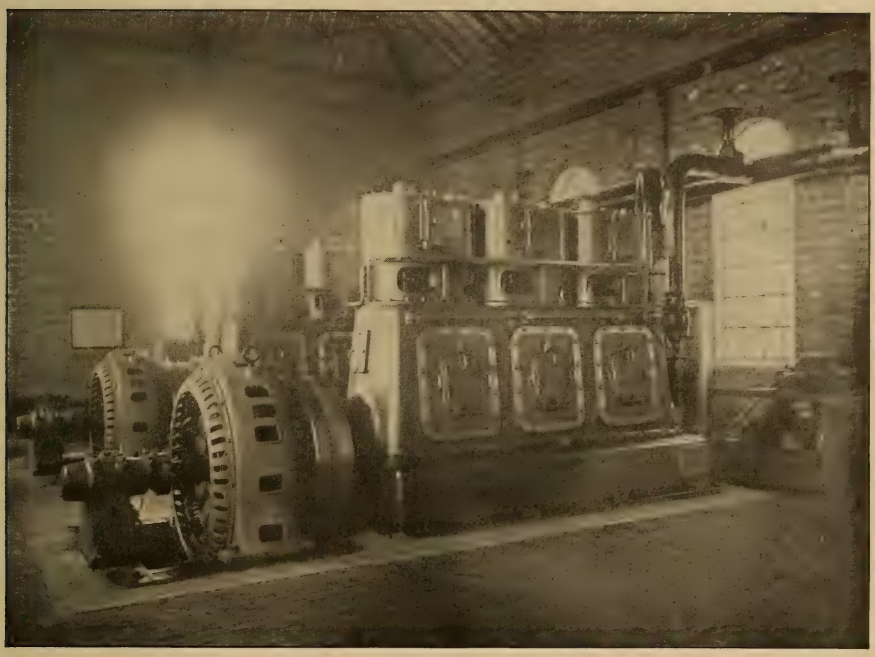


FOUR 400-K. W. ALLIS-CHALMERS GENERATORS AT THE YORK RUN PLANT OF THE H. C. FRICK COKE COMPANY

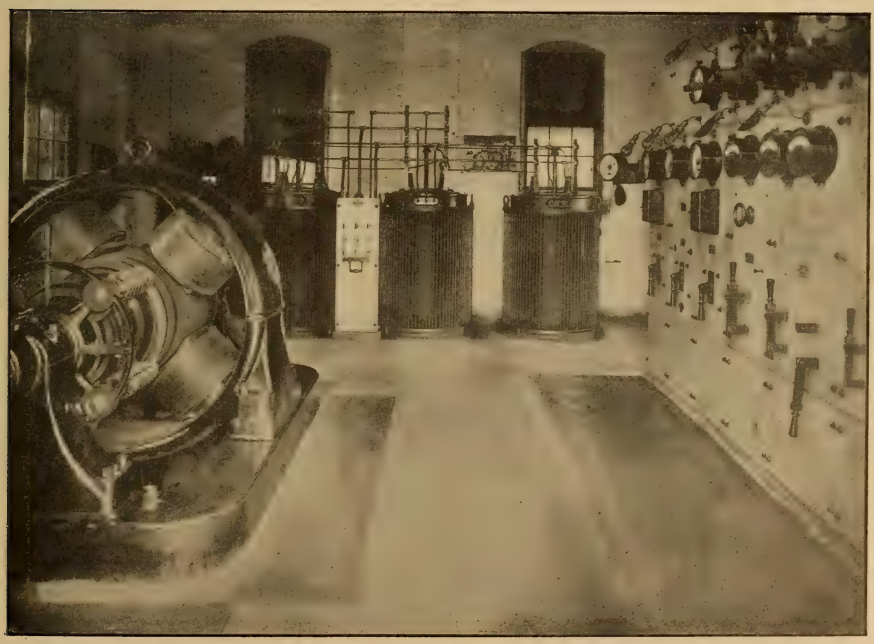


REAR OF MAIN SWITCHBOARD AT YORK RUN PLANT. ALLIS-CHALMERS CO., CINCINNATI

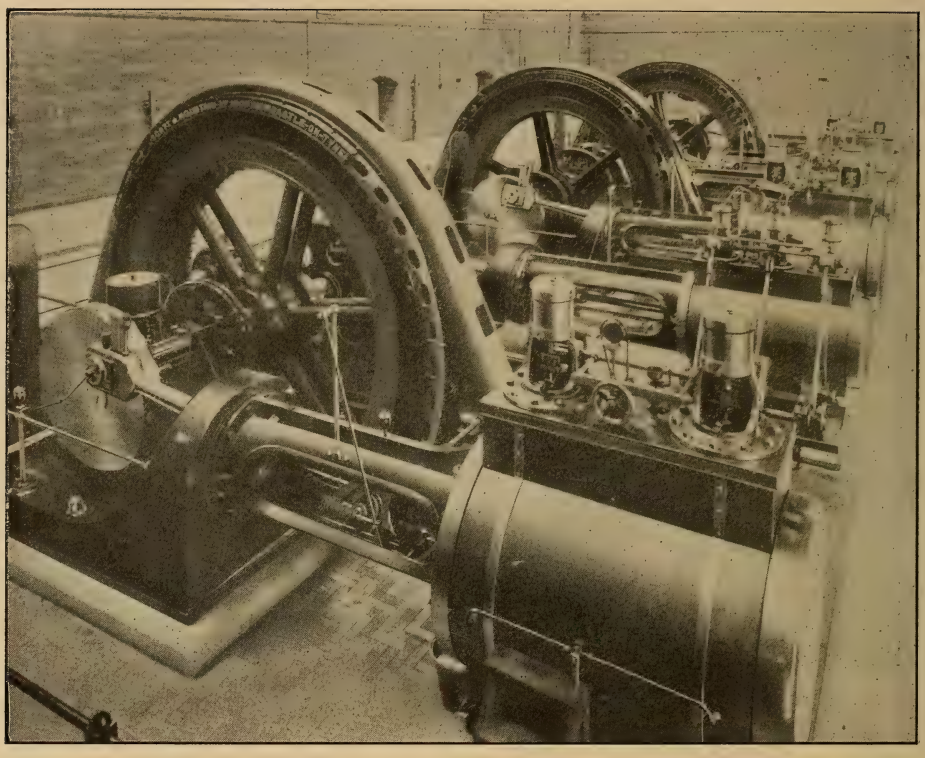
the old spear-rod pump to the modern high-lift centrifugal pump is a wide step, largely influenced by electricity. This is a case giving a fair example of the road which mechanical engineering has traveled since its first introduction to mining. We find that the electrical drive is only the last link in a chain tending towards increased speed and minimized weight, largely due to the change from reciprocation to rotation. England, the classical soil for the development of mining machinery, has amongst its collieries several which form quite a museum of the development of pumping machinery. We find there the old Hathom Davey pumping engine, with about four strokes per minute, which has been typical for all the mining installations for the greater part of the nineteenth century. The reason why mining engineers adhered to this machine so obstinately were several, the foremost being that the machine is well within the limits of the ability of the ordinary colliery man—it can be built practically on the spot and kept under repair without outside assistance; the second important reason was the fear of having steam underground. But with the increased depth and quantity of water, the limit of this spear-rod pump was soon reached; the difficulty of controlling heavy masses and the appreciation of the valuable space which these rod pumps took up in the shaft forced engineers to go in for a quicker running system, even at the disadvantage of taking steam underground and being dependent on outside manufacturers. This was how the duplex steam pump originated, with a speed of 40 to 50 strokes per minute. Further developments in increase of speed were largely influenced by the introduction of electricity into mines, and the electrical motor adapted the pump to its own merits, first increasing the speed of the reciprocating pump (Riedler, Gutermuth, etc.), and then evolving the design of high-speed rotating pumps which are now standard for large mine pumping devices. This last step alone, the change from the high-speed recipro-



TWO THREE-PHASE GENERATING SETS BUILT BY SCOTT & MOUNTAIN FOR KENT COLLIERIES, LTD., NEAR DOVER



ROTARY CONVERTER AND TRANSFORMERS AT SUB-STATION OF YORK RUN PLANT. ALLIS-CHALMERS CO., CINCINNATI



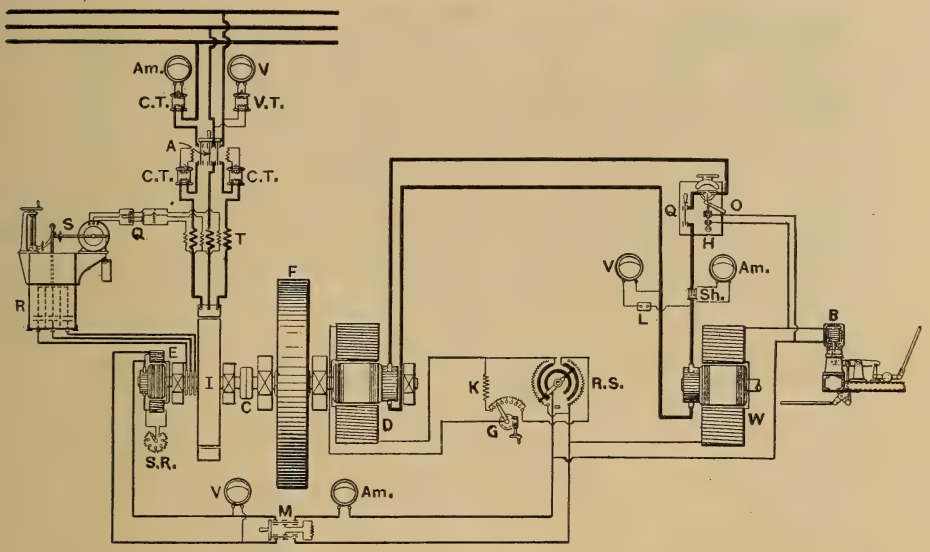
THREE 300-K. W. THREE-PHASE SETS AT THE MANTON COLLIERY OF THE WIGAN COAL & IRON CO.
GENERATORS BY SCOTT & MOUNTAIN, ENGINES BY ROBEY & CO

cating pump to the centrifugal pump, reduces the weight of the pump by more than 50 per cent.

WINDING

Of late winding machinery has also been included in this development. Here the main difficulty—the doing away with the alternating movement of the cages and all the disadvantages connected with the acceleration or retardation of the journey—have not yet been overcome, although a proposal has been made to lift coal continuously by means of elevators; but this idea is rather premature, as such powerful elevators as would be required for that purpose have not yet been designed. It is quite possible, however, that, at a future date, a modification of this idea may be carried out, sub-dividing the total lift into parts of, say, 250 feet, and working the various elevators in series. We may, therefore, expect at some future date to see the raising of coal performed in a similar manner to that of its greatest enemy, the water, with a corresponding consumption of energy from the power plant running the colliery; in fact, pumping the coal would be the ideal from a power-saving point of view. Those who have followed the latest progress of electrical engineering will easily recognize that this pumping can be practically accomplished to-day by introducing a method of electric winding which is known under the name of "Ilgner system," and which offers such a characteristic indication of the application of electricity that a short description will not be out of place.

A winding engine built on this system and installed at the Donnersmarkhuette, Upper Silesia, is shown in the diagram. The weight of coal



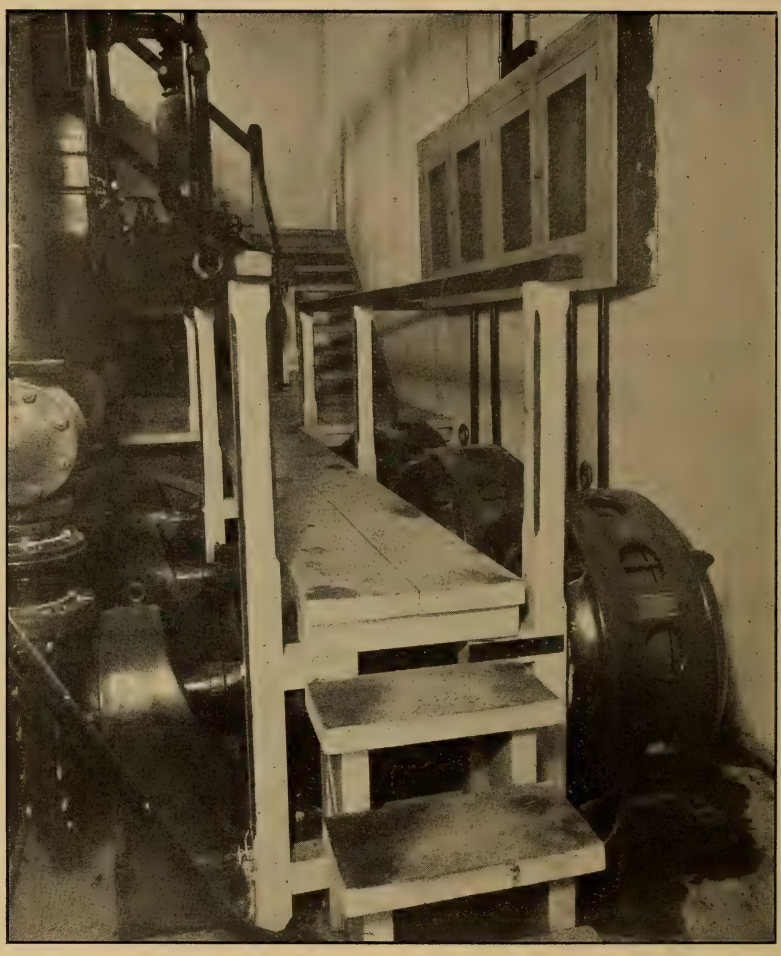
THE ILGNER WINDING SYSTEM AS INSTALLED AT THE DONNERSMARCKHUETTE

I, Induction Motor with Slip-rings; F, Flywheel; C, Elastic Coupling; D, Starting Dynamo; E, Exciter Dynamo; S, Slip Regulator; R, Starting and Slip-regulating Resistance; T, Transformer for Slip Regulator; C T, Current Transformer; V T. Voltage Transformer; S R, Shunt Rheostat; R S, Reversing Switch; O, Overload Cut-out; G, Safety Rheostat for Field; Q, Quick-break Switch; A, Automatic Oil Switch; M, Main Field Switch; H, Short Circuit Switch; K, Resistance for taking up the "Kick" of the Shunt; Am, Ammeter; V, Voltmeter; Sh, Shunt; L, Series Resistance; B, Magnet for the Brake Mechanism; W, Winding Motor.

lifted per trip is 1 ton 5 cwt. from a depth of 1,650 feet, and with a maximum speed of 16½ feet per second. The drums are each 12 feet 6 inches in diameter and 3 feet 7 inches in width over all. The load is divided between two tubs, each weighing 7½ cwt., empty, and the weight of the cage, etc., empty, is 5 tons, it being designed to eventually take much heavier loads as the mine is deepened. A one-inch circular winding rope is used.

The continuous-current, shunt-wound winding motor is separately excited at constant voltage from the exciter *E*, as shown in the drawing, and runs at 150 revolutions per minute with a normal output of 230 H. P. during winding, and an output up to 400 H. P. during starting. It drives the winding drum in this plant by means of toothed-wheel gear with a reduction ratio of 1 to 6. The drum is fitted with brake blocks. Under normal working conditions the brake is actuated through compressed air by means of a hand lever, but a drop weight serves as a safety brake, and is actuated through depth-indicating gear or, in the case of the current being interrupted, by a magnetic brake *B*. The drop weight is kept balanced by a compressed air cylinder, but can also be released by hand.

The Ilgner converter plant includes a three-phase induction motor connected to the supply mains, giving a theoretical speed of 500 revolutions per minute and an output of 125 H. P. It will be noticed at once, therefore, that while the winding motor must work up to 400 H. P., the three-phase induction motor in this case is only of about one-third this output. The induction motor is coupled by means of a flexible coupling to a shaft carrying a cast-steel fly-wheel weighing 15 tons, with a diameter of 11 feet (maximum peripheral speed about 280 feet per second), and mounted on the same shaft is a compensated continuous-current generator of the Deri system for an output of 72 kilowatts.

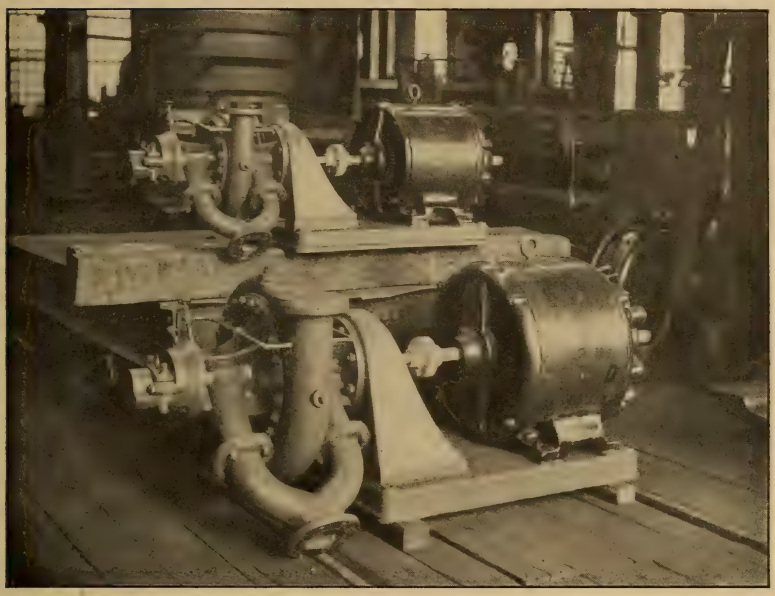


ALLIS-CHALMERS INDUCTION MOTORS DRIVING CENTRIFUGAL PUMPS

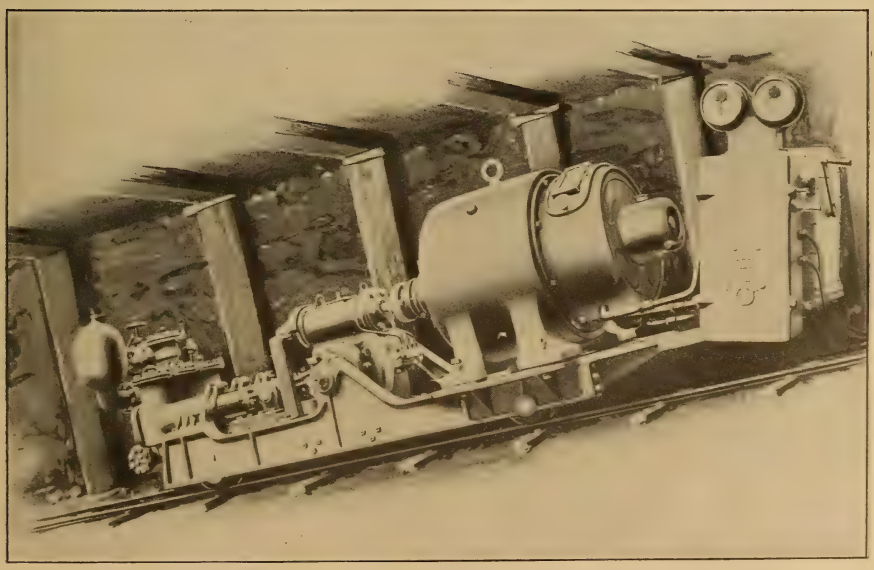
Beyond the left-hand outer bearing is an exciter set, consisting of an 81-kilowatt, 220-volt, compound-wound machine, which excites the field of the continuous current generator and the winding motor.

The starting and speed control of the winding motor is effected by means of the Leonard system, by alteration of the excitation through the reversing and controlling switch *R, S,* shown in the diagram. One of the special features of the switching arrangements in this system is that the controlling lever of the rheostat *R, S* is so designed that for each position to which it can be put by the driver there is a definite fixed speed for the winding motor, no matter what the load may be which is being lifted or lowered. Also the driver can electrically brake the winding motor, either quickly or slowly, by suitably adjusting the lever so as to make the winding motor run as generator and so help to speed the flywheel.

The Ilgner converter works in the manner described below. The energy, in the form of three-phase current from the network, is brought to the induction motor coupled to the fly-wheel and the continuous-current generator. The latter, especially when the winding motor first begins to run, must commutate a current



SINGLE-STAGE, ELECTRICALLY DRIVEN CENTRIFUGAL PUMPS BUILT BY THE ALLIS-CHALMERS CO. FOR THE DELAWARE, LACKAWANNA & WESTERN CO. CAPACITY 5-INCH, 800 GALLONS PER MINUTE; 3-INCH, 250 GALLONS

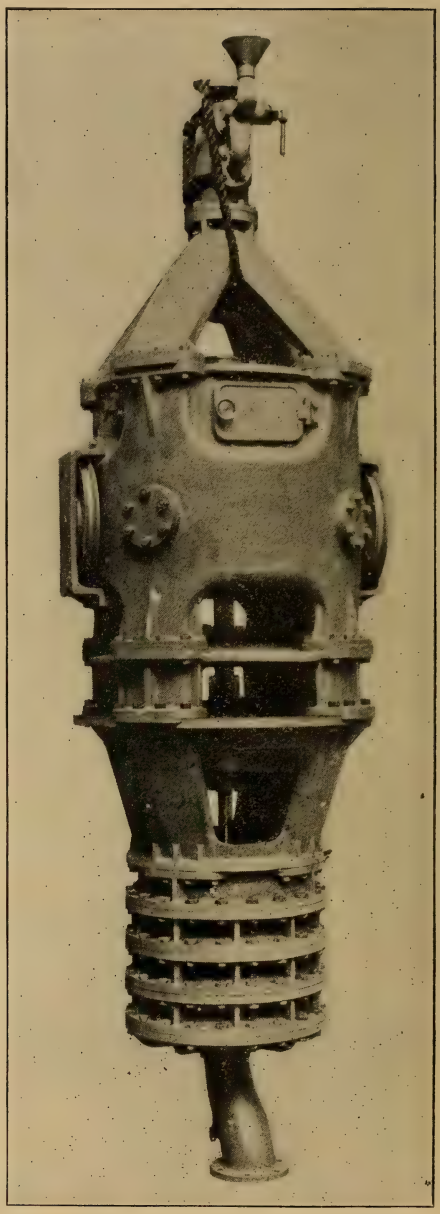


SPECIAL PUMPING SET FOR UNWATERING DIP. THREE-THROW PUMP, 25 HORSE-POWER MOTOR. ERNEST SCOTT & MOUNTAIN, LTD., NEWCASTLE-ON-TYNE

many times greater than the normal full-load current with almost no voltage pressure and with the brushes in neutral position. For this reason a so-called "compensated" continuous-current generator on the Deri system is used, and in this machine, by means of the special winding, any cross-magnetic action of the armature is completely negatived, and perfectly sparkless commutation is obtained for all loads and voltages.

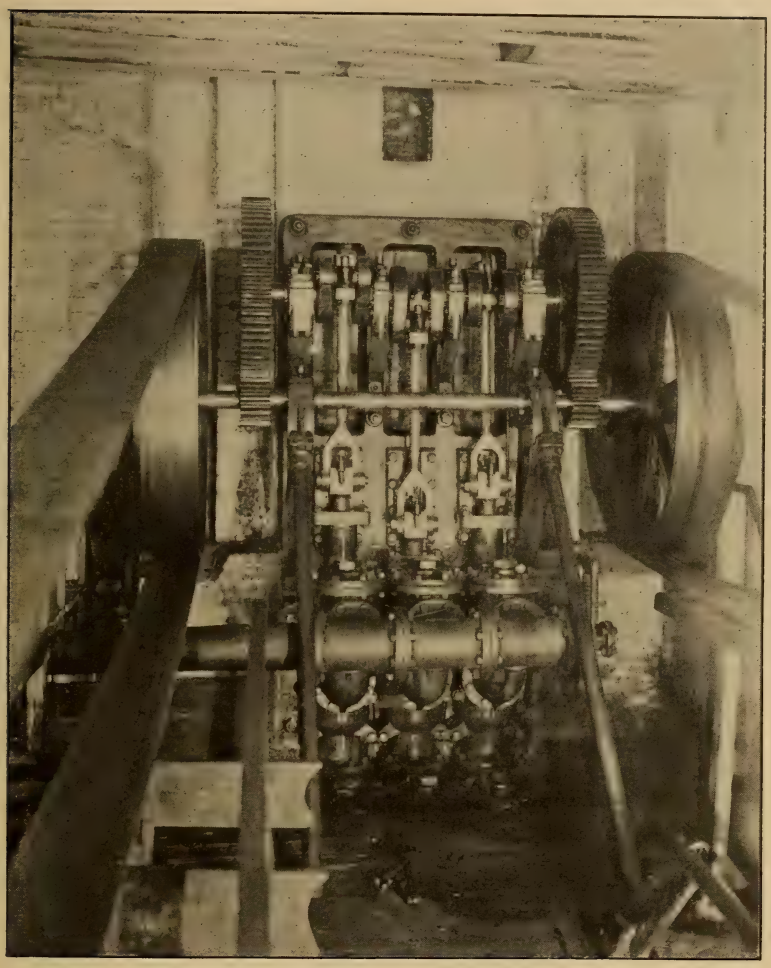
The converter serves two purposes: firstly, it converts the high-tension three-phase current to continuous current, and secondly, its still more important function is to secure an almost complete avoidance of the otherwise heavy "peaks" of current on the supply mains, brought about through the starting of the winding plant. This is effected by the arrangement that, at the starting of the winding motor and during its acceleration period, the extra demands of the gradual switching out of the resistance, a sudden sinking of the current in the induction motor below its normal value is prevented, and it is gradually sent up again to its correct speed. In order to bring the converter set to a stop quickly, when required, a brake block is arranged below the fly-wheel rim, and this can be applied by means of a hand wheel and spindle, and is fitted with water cooling, conveniently controlled by a tap near the brake spindle. The converter set is kept continually running during the hours of winding.

The influence of electricity in the winding problem can also be seen in other directions. Of course, between the high-speed of the ordinary electric motor and the low-speed of a winding drum there is a large difference, and in the case of heavy powers, where intermediate gearing is inconvenient, the electric motor has to make the climb down to a greater degree than the advance of the drum in the other direction. Some progress, however, has also been made in this direction. In Germany Koepe wheels



SPECIAL UNWATERING PUMP FOR SHAFT USE. ERNEST SCOTT & MOUNTAIN, LTD., NEWCASTLE-ON TYNE

are being run at a higher speed than usually adopted, the ratio of the pulley diameter to the rope diameter being considerably reduced; in one instance a 2-inch diameter rope runs over a pulley of 11 feet 8 inches diameter with perfect success.



THREE-THROW VERTICAL MINING PUMP; CAPACITY 600 GALLONS PER MINUTE AGAINST A HEAD OF 750 FEET. ERNEST SCOTT & MOUNTAIN, LTD., NEWCASTLE-ON-TYNE

All this high-speed rotating machinery adds considerably to the flywheel effect of the whole system. This latter point must not be overlooked. Each individual rotating machine connected to the mains of the power supply improves the system, helps in keeping the voltage constant, helps the prime movers in overcoming heavy peaks of the load, and brings the strain on the boilers to a certain average, and the latter point is the key for the economical operation of a mine. From this point of view centrifugal pumps show another great advantage over reciprocating pumps.

COMPRESSORS

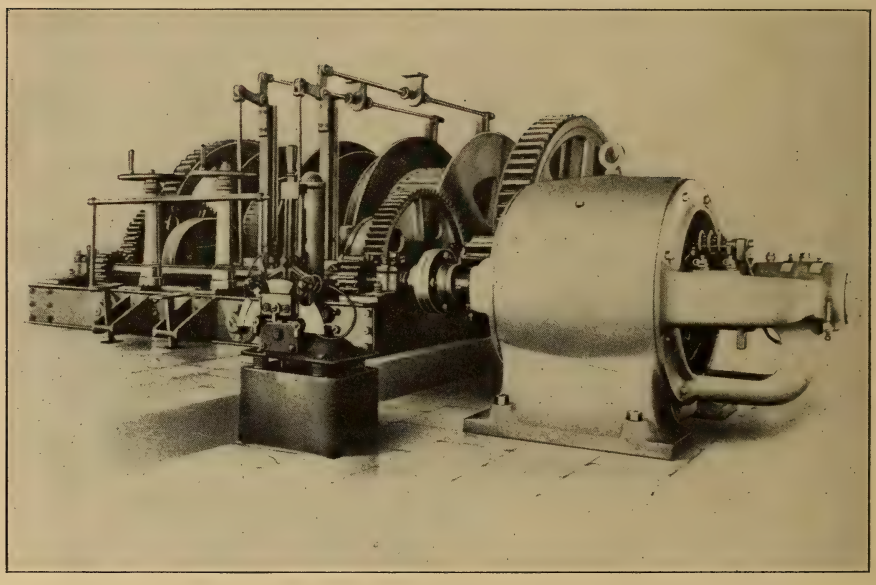
Bearing in mind the availability of the high-speed rotative electric motor for mining service, designers have of late given serious attention to the construction of turbo-compressors for direct connection to electric motors. These machines, constructed upon the same general principle as the multi-stage centrifugal pump, have already given good results, even with fairly high pressures, and it is probable that for certain purposes

they will attain a commercial importance.

DRILLS AND COAL CUTTERS

The influence of the electric motor is also evident in the design of drills and coal-cutting machinery, the possession of a convenient portable rotating motor giving prominence to machines using rotary cutters.

These applications are well shown in the illustrations, these including



ELECTRIC WINDING GEAR FOR A DEPTH OF 400 FEET. DIRECT-CURRENT MOTOR OF 75 HORSE-POWER WITH LIQUID CONTROLLING SWITCH. ERNEST SCOTT & MOUNTAIN, LTD.

the machines built by the Jeffrey Manufacturing Company and the Sullivan Machinery Company, in the United States, and by Messrs. Mavor & Coulson, in Great Britain.

Electric coal cutters of the rotating bar type are especially adapted for use with the longwall system, and Messrs. Mavor & Coulson give some interesting data concerning performances in this respect. As a typical example, the performance of a pick-quick bar cutter of medium size is given, using a direct-current motor of 18 horse-power, undercutting the coal to a depth of 3 feet. The section and plan of the sema are shown in the illustrations, and the output for a month's working was 3,116 tons of coal, involving cutting for a lineal distance of 4,140 yards, giving an average output of 125 tons per shift for twenty-five shifts worked during the month.

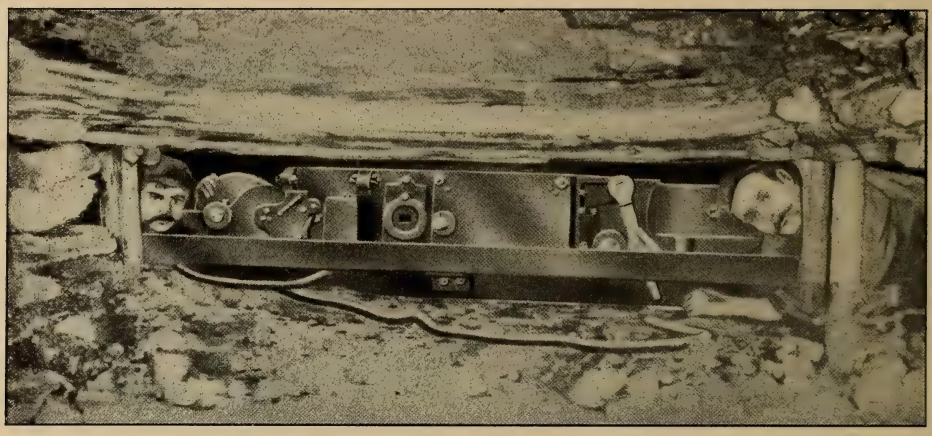
The total length of the face, 230 yards, was cut in an average shift of twelve hours, the average lineal cut being 15 inches per minute. Concerning the consumption of power, with 450 volts pressure at switchboard, current 27 amperes, the power delivered to the circuit was 12.2 kilowatts, the brake-horse-power of the motor being 13.5, which works out to 49 electric units per square yard cut and 0.77 unit per ton produced.

VOLTAGE REGULATION

The question of the regulation of voltage, especially with alternating-current installations, is a matter which is by no means definitely settled. At present things are in a state of compromise, and opinions as to the best method of procedure are still far from being unanimous. What

ELECTRIC COAL MINING MACHINE. SULLIVAN MACHINERY CO., CHICAGO

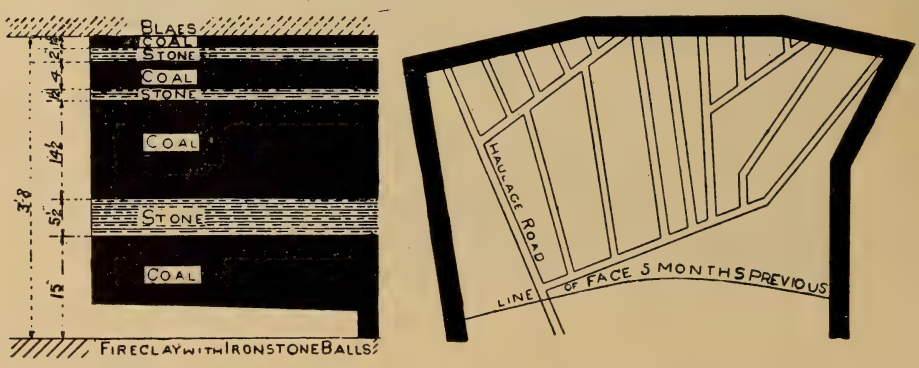
SULLIVAN ELECTRIC COAL MINING MACHINE CROSSING THE FACE IN A SINGLE OPERATION. WITHOUT WITHDRAWING THE MACHINE FROM THE COAL OR MOVING JACKS



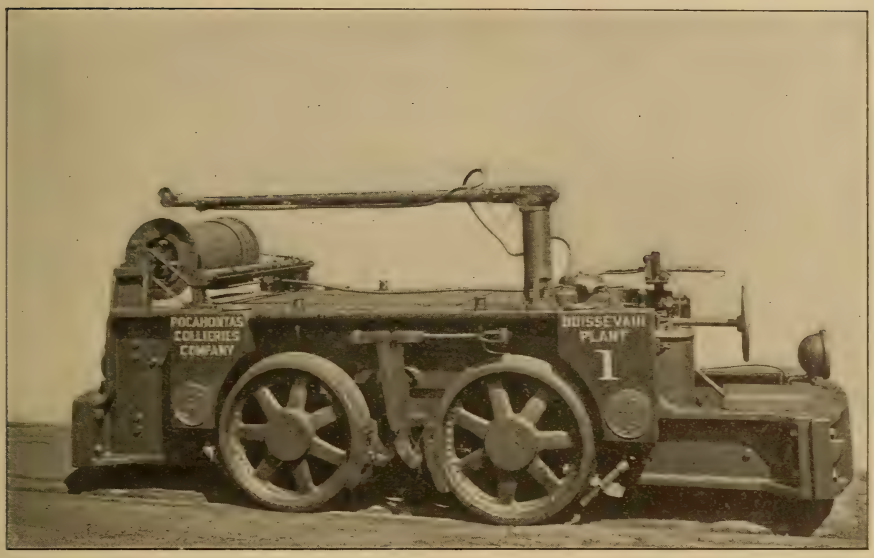
SMALL SIZE PICK-QUICK COAL CUTTER WORKING IN SEAM 16 INCHES THICK. MAVOR & COULSON, LTD., GLASGOW

electrical engineers mostly fear is the sudden throwing of heavy loads on and off the supply mains, a natural occurrence in connection with winding or hauling engines. The chief fear is that when suddenly throwing an induction motor, with all the heavy masses attached to it, on the forced synchronous speed of a three-phase system, a heavy drop of the main voltage would be the consequence, and unless special means were provided this would certainly have bad consequences. In the ordinary power plant, where excitation is effected by means of a motor-generator, this reduced voltage would possibly mean an overload on the motor, and a reduced speed and reduction in voltage on the generator in consequence, which again would increase the voltage drop of the main alternator. Apart from other means, therefore, a separately and independently driven exciter should always be provided if heavy peaks of load are expected. Further, the ordinary speed regulator generally used for steam engines does not work quickly enough to prevent the voltage drop. The Tirell regulator, developed by the General Electric Company, of America, meets this case very well, and has, therefore, been installed in numerous installations on the Continent.

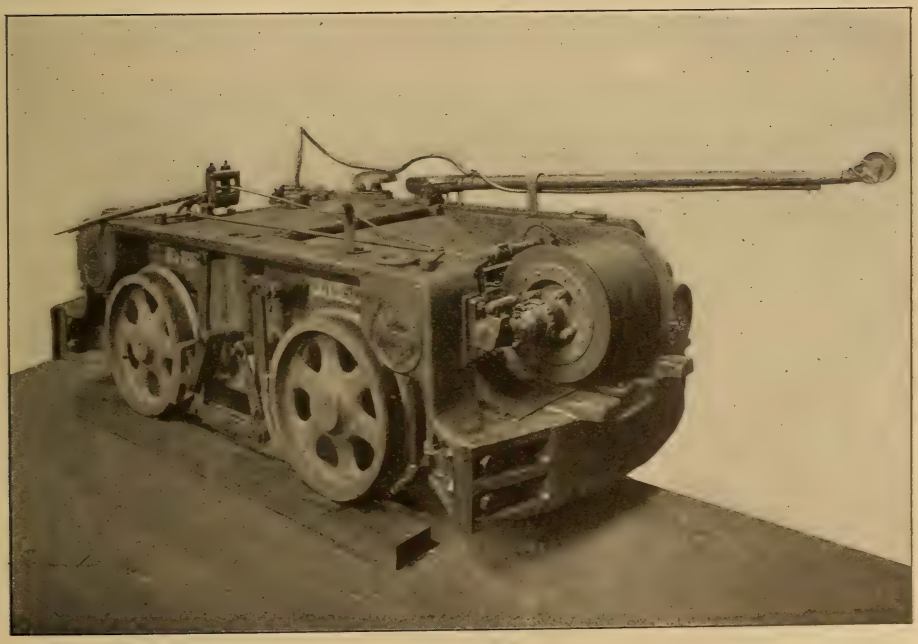
But even granting that there are still considerable difficulties in dealing with sudden rushes of load, this does not justify engineers in stopping half-way and adopting the old, clumsy, inefficient and unreliable



FIVE MONTHS' WORK WITH THE PICK-QUICK CUTTER. SCALE OF PLAN ABOUT 230 FEET TO THE INCH

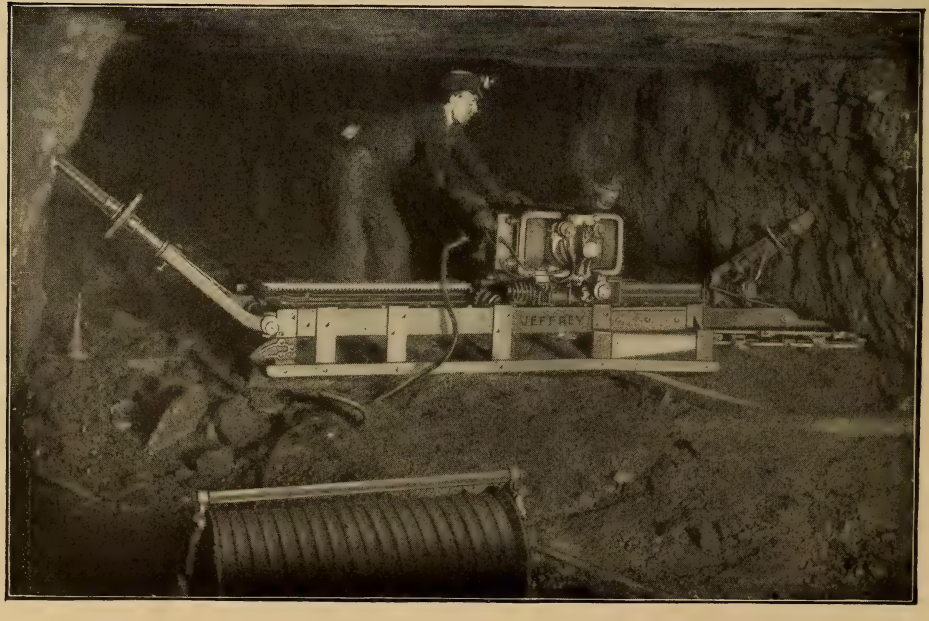


BALDWIN-WESTINGHOUSE ELECTRIC MINING LOCOMOTIVE AT THE BOISSEVAIN PLANT OF THE POCAHONTAS COLLIERIES CO

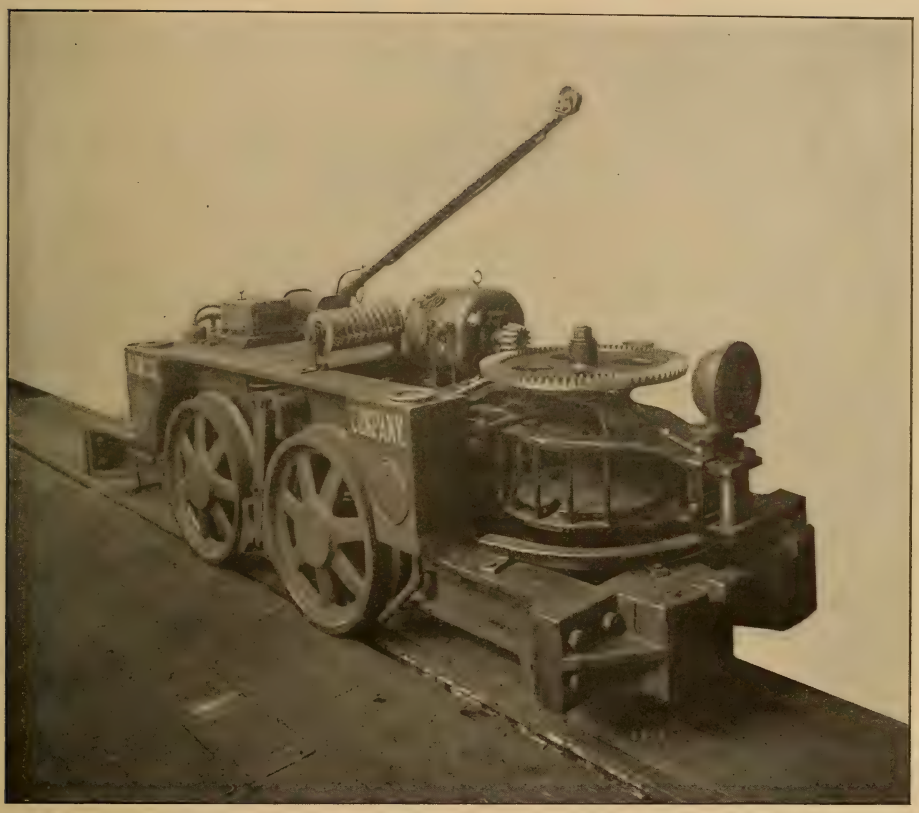


NEW RIVER COLLIERIES CO., BALDWIN-WESTINGHOUSE ELECTRIC MINING LOCOMOTIVE

JEFFREY ELECTRIC COAL DRILL IN OPERATION. CANNELTON COAL & COKE COMPANY



JEFFREY ELECTRIC CHAIN COAL MINING MACHINE CANNELTON COAL & COKE COMPANY



BALDWIN-WESTINGHOUSE ELECTRIC MINING LOCOMOTIVE BUILT FOR THE NAOMI COAL CO.

means of intermediate claw couplings, belts or ropes between the motor and the hauling or winding drums, as this does no credit to the electrification of collieries at all. If the control of an electric haulage is not at least quite as simple as that of steam haulage, colliery owners generally will not be induced to adopt it, as they all realize that simplicity in control and readiness to work are paramount to all other considerations.

During the past few years, however, the design and construction of controlling devices has developed into an independent and highly specialized business, and it is entirely practicable to introduce into colliery power systems such efficient controlling devices as altogether to overcome the early objections to electric power.

Electric haulage in mines may be effected by continuously running cables, and on the Continent a number of mines are thus equipped. This method has advantages, but it involves the provision of two tracks in the seams, and in many instances this is impracticable. Electric locomotives, using either storage batteries or taking the current by trolley from overhead conductors, are extensively employed, and the illustrations show some recent electric locomotives of this latter type, as built by the Baldwin-Westinghouse Companies.

Electricity, then, has shown itself well adapted for the multifarious applications of power demanded in coal mining operations, including pumping, winding, air supply and underground traction, as well as to the actual cutting of the coal.

THE FUTURE OF THE IRON AND STEEL INDUSTRY FROM A BRITISH POINT OF VIEW

By T. Good

THE prospects of the iron, steel and kindred trades merit strict attention just now. The world's demand for iron goods increases more rapidly than its demand for any other class of commodities, and it is more than desirable that Great Britain, as a manufacturing nation, should obtain and retain an adequate share of this growing trade in iron and iron goods. We cannot recall the past—a past in which we have been relegated from the first to the third position as an iron producing country—but how we shall meet future competition is a question of the greatest interest.*

Viewed from one particular standpoint, the outlook is not very bright. In the first place we must admit that the present activity in our iron trades is largely due to the recent abnormal pressure of demands in Germany and America, together with the concurrent slackening of competition from those countries. Should that abnormal pressure be relaxed for any great length of time, or should production largely exceed consumption in Germany and America, we may very likely be involved in a severe struggle. At the moment of writing, there are unmistakable signs of relaxation in both countries. Not only this, but our rivals, both German and American, are very substantially increasing their productive capacities. In these circumstances the pessimist sees nothing before us but a period of acute depression. He argues that Germany will soon be making 15,000,000 tons of pig iron a year, and that the United States will soon be making 30,000,000 tons a year; that in both countries demands are falling off; that periods of great activity are always followed by spells of stagnation,—that an iron boom is always succeeded by a panic; that with decreasing demands and increasing production our rivals will soon have huge surpluses available for export, and that those surpluses will be dumped upon our markets, and upon other markets in which we are interested, in such quantities and at such prices that we shall be obliged to shut down our furnaces and turn adrift our workers wholesale. But that is only one aspect of the problem. We shall venture to draw attention to others presently.

However, granting for the moment that there is real danger of a severe competitive struggle in the near future, what measures are we taking to render ourselves fit and efficient for the contest? No less an authority than Mr. J. Stephen Jeans, in his recently published book*, says: "The average (British iron and steel) profits are not so considerable as they are in some other countries, and it is probable that they will relatively diminish, for two reasons—the first because the expenditure on repairs, renewals and reconstruction is not sufficient to keep plants up to the highest point of efficiency; and the second because a sufficient amount of gross profits has not generally been allocated to the risks of manufacturing accidents, renewals and sales." Here we have it on a high authority that our plants are not as efficient as they might be, and that our cash

* This article was written some time before the recent financial flurry in the United States.

* "The Iron Trade of Great Britain," Methuen, London.

reserves are not substantial—in a word, that we are not prepared for the struggle which is frequently foreshadowed.

On the other hand, Sir Charles McLaren, an undoubted authority, takes a very different view of the situation. Sir Charles says: *"The profits earned in 1901 not only sufficed to provide the very best technical appliances in all our large metallurgical and engineering concerns, and to pay handsome dividends to the shareholders, but have placed these industries on a footing as permanently sound as any in the world. Colliery, steel and shipbuilding costs have been reduced to the lowest point. Better trade methods have been adopted. Large cash reserves have been created. Highly-trained technical men have been placed at the head of departments, and there is no labour-saving machine invented by German, American or French, skill which has not its place now in our great works side by side with the best British inventions. So far from being behind any other country, it is not too much to say that the best steel plants now in Cleveland, in Lanarkshire, in South Wales and the Midlands, are well ahead of anything that can be found abroad."

These two conflicting views, presented within a very few months one of the other, by two of our greatest authorities deserve more than passing notice. It is worth remarking that Sir Charles, in praising British enterprise, only alludes to the best plants. While it is true that, broadly and generally speaking, vast improvements have been effected recently in many of our industrial establishments, and while many of our plants may be equal to the best in other countries, it is also true that we have some of the other kind still in existence, and, undoubtedly, Mr. Jeans had these latter in mind when he wrote that particular passage just quoted from his valuable book.

While we cannot accept Mr. Jean's structures as being applicable to the whole, or even to the majority, of our works, on the other hand, we do not quite agree with Sir Charles McLaren when he says that "costs have been reduced to the lowest point," even in the best of our works. We have ventured on previous occasions to point out, through the pages of this magazine, directions in which economies might be effected in our costs of production. But, for the moment, we leave that point. It is quite true, however, that within the last two or three years a marked change for the better has been brought about in our iron, steel and engineering industries. This change has not been proclaimed from the house-tops, as is usually the case with our rivals' improvements, but it is a fact accomplished, none the less. There has recently been an industrial awakening in Great Britain! The recent balance-sheets of all our leading iron and steel companies bear eloquent testimony to the progress that has been made. Not only have improved types of furnaces and machinery been adopted by most of our manufacturers, but more practical and alert managers and foremen are now controlling our works and workers. Improved mechanical appliances and improved control over labour have brought substantial economies in cost of production, alike in materials and in labour. Then again, steel makers have become colliery proprietors and ironstone miners on the one hand, and shipbuilders and engineers on the other, thus combining, in some cases, every phase of production from mining the minerals to the building of a ship and her engines under a single management. Americans and Germans are not the only people who have improved their methods in recent years. Yet there is room for further improvements in this country, and it is only by bringing our workers, our appliances and our business methods up to the highest points of efficiency that we can hope to retain our

* "Financial Review of Reviews," October, 1906.

position as an industrial nation.

So far as the commercial outlook, to which we have already briefly alluded, is concerned, it is safe to say that a feeling of uneasiness is coming over the British steel trade. With reports of a slackening of the pressure which has been so long prevalent in America and Germany, the idea is gaining ground that the boom is practically over, and fears of a rapidly-approaching reaction are being entertained. Are these fears well founded? We are aware that trade usually ebbs and flows, that the whole history of the iron and steel industry is marked by severe fluctuations; that the present spell of abnormal activity has lasted a fair length of time now; and should there be serious decline in the demands of American or Germany, or of both countries, with consequent depression here, there would be little cause for surprise. We are aware, too, that under existing fiscal conditions there is danger of our markets being deluged with dumped steel from abroad, whenever our rivals may have a surplus largely in excess of their own requirements. We are alive to the dangers of the situation, but we are certain that the dangers are too frequently exaggerated. At any rate, we think we may usefully draw attention to other circumstances connected with the problem of future competition—to circumstances which lead us to hope and believe that the future development of the iron and steel trade will be much more steady, stable, and consistent than its past progress has been.

This industry, especially in the United States, has hitherto been a huge gamble; the ironmaster has been, in Mr. Carnegie's words, either prince or pauper. Rash and inexperienced speculation, excessive capitalization, and slack financial methods in general, lack of organization, and the resultant fits and starts and panics are the chief characteristics of the annals of the American iron industry. But organization is rapidly taking the place of chaos, and for this reason we do not think it safe to forecast the future from experience of the past alone. We must recognize that new conditions are now governing this industry, alike in America, in Germany, and in Great Britain. Because a certain thing has happened in the past, under certain conditions, we have no guarantee that the same thing will happen in the future, under totally different conditions.

In America, the United States Steel Corporation, with all its faults, has had a steadying influence over the trade, and seems destined to dominate and discipline the industry of that country still more in the future. The trust made some costly mistakes in the early days of its existence, it had to pay exorbitant prices for some of the concerns it absorbed, and it failed in its primary object—it failed to obtain absolute control over all the steel production in the country—and its doom was confidently predicted by many authorities. The seventh year of its life finds it full of vigour and occupying a strong position. Of course, nearly one-half the steel production of the United States remains outside the trust, and it is well so, but even among the independent producers an improved understanding seems to be coming into existence. At any rate, the American iron trade in general is now on a better footing industrially and financially than it was a few years ago, or at any previous period in its history. While, from one standpoint, this may indicate a stronger competitive position, increased powers of dumping, for example, and tends to frighten some of the pessimists in this country, it would also seem to be a guarantee that we shall not see, in the future, the rapid and extreme fluctuations in price which we have hitherto been accustomed to witness.

Then as regards Germany, what are the facts? The Steel Syndicate (Stahlwerksverband), formed a little

more than three years ago, and just recently renewed for five years, has organized, strengthened and disciplined the iron and steel trade of Germany in a remarkable manner. The financial, as well as the industrial, position of the German steel trade has been materially improved. It may be that home demands in Germany are falling off, and there may eventually be a surplus available for dumping into this country. But the last period of dumping from that quarter did not give entire satisfaction to the dumpers, and it is just possible that the interests in Germany, which are opposed to bounty-fed exportation, below cost price at the expense of the home consumer, will be strong enough to prevent a recurrence of what we saw a few years ago, when German steel was sold cheaper in England than in Germany. We do not say it will be so, but we do contend that, with a strong organization, such as now governs the German steel trade, and with the trade in a much better financial position than it was a few years ago, the inducement to dump, rather than stock, should production largely exceed consumption for a time, will be much less strong than on some occasions in the past.

Moreover, it is well within the bounds of possibility that before current contracts are worked off, the pressure of demands, both in Germany and America and elsewhere, will be renewed. The output of practically every furnace is bespoke for some considerable time yet, and the present lull in placing orders may prove to be merely temporary. There are certainly no signs of any permanent check in the world's demand for iron and iron goods. Steel is being put to an ever increasing number of new purposes. That, we think, is the most reassuring feature of the situation.

One of the possible dangers of the future foreign competition is that such competition will be directed by trusts and syndicates more powerful than in the past, while the opposition we may be able to offer will be that of individual firms, that is, assuming that we unduly harass, either by legislation or the pressure of an intolerant public opinion, the reasonable development of the combination movement among our manufacturers, or, if through their inherent conservatism, our manufacturers fail to meet their organized competitors by organized resistance. But even this danger is gradually passing away. We are coming to recognize—indeed, we are being driven by our rivals to recognize—the need of organizing our industrial forces for the purpose of combating international competition.

Trusts, syndicates and combines have not hitherto flourished in this country to anything like the extent which they have in American and Germany; but our iron and steel trades have been largely dominated by various combinations, none the less. Not only have we to deal with combined labour in our workshops, but we have to meet in the markets of the world highly organized trade rivals. There have been occasions when, and markets in which, our iron and steel makers have been practically at the mercy of American trusts and German syndicates, those huge organizations which, despite all their faults, have stimulated industrial enterprise and commercial expansion in a positively wonderful manner. The lesson for this country is clear, and many of our leading manufacturers and commercial men are profiting by it. What combination has done in Germany and America it can do—and, we venture to say, will do—in Great Britain. And with this difference, our manufacturers, in organizing their forces, will be careful to avoid some of the initial errors which were made by their rivals. The industrial combination movement is now very pronounced in this country, and consolidation of interests and economies in production, together with sound capitalization, effi-

cient management, and a better feeling growing up between the labour unions and the employers' associations, will render our industries stronger, from the competitive point of view, than they have been for a generation past. We believe that the iron industry, alike in America, in Germany, and in Great Britain, has quite recently taken a new lease of life, and that the "booms" and panics which have hitherto characterized this trade are, to a very considerable extent, things of the past. The trade may have its "ups and downs," but we venture to predict that they will not be near so pronounced or violent as has hitherto been the case.

Viewing the problem of international competition in iron and steel from a purely British standpoint, we can see little cause for alarm in the fact that America and Germany have got ahead of us on the basis of production, and are now increasing their productive capacities at a greater rate than we are. We must remember that those countries have populations larger than ours. It is true that in the past we were not always as alert as we might have been, and that we allowed our rivals to beat us in some respects; it may be true that to-day we do not display an ever-ready adaptability to new ideas, times and circumstances; it is quite true that we permit the results of economic fallacies and dangerous political doctrines to fetter our enterprise; it is painfully true that we fail to duly encourage, but prefer to harass and burden, industrial development; it is an indisputable fact that we sacrifice public well-being to certain ancient, but private monopolies, and that we check heavily industrial progress by pettifogging legislative interference; but, for all that, there need not be much anxiety concerning our future as an iron and steel producing, manufacturing and exporting country. At any rate, such dangers as may threaten are not natural, or fundamental, or insurmountable; neither are they technical nor industrial to any great extent, but are commercial fiscal and political, and with a broadened public opinion can be—and, through pressure of competition, will be—avoided or mitigated.

The one supreme fact upon which we Britishers can congratulate ourselves is, that to-day, despite all that is said about the wonderful natural resources and mechanical skill and business enterprise of our great rivals, we can profitably produce pig iron—the foundation of the steel and engineering trades—just as we can build ships, at a cost below that of other countries. While that remains the case there is no valid reason why foreign competition should frighten us—it should simply spur us on to improvement and progress. In these islands we have good coal in abundance; we are not without valuable deposits of iron ore, and we have ample foreign supplies of ore within the easiest possible reach; we have coal, ore, furnaces, and shipping ports practically side by side; nor do we lack capital or labour; but to develop to the best and fullest extent our resources in men, money and materials, we need intelligent organization. And we need some of the present burdens on industry lightened. We want ground rents, mining royalties, railway charges, local rates and imperial taxes pulled down to a reasonable level.

CRANKSHAFTS FOR INTERNAL-COMBUSTION ENGINES

By George F. Fuller

AMONG the machine processes which have undergone modification and improvement as a result of the demands created by the development of the internal-combustion engine, the forging of multiple crankshafts is an interesting example.

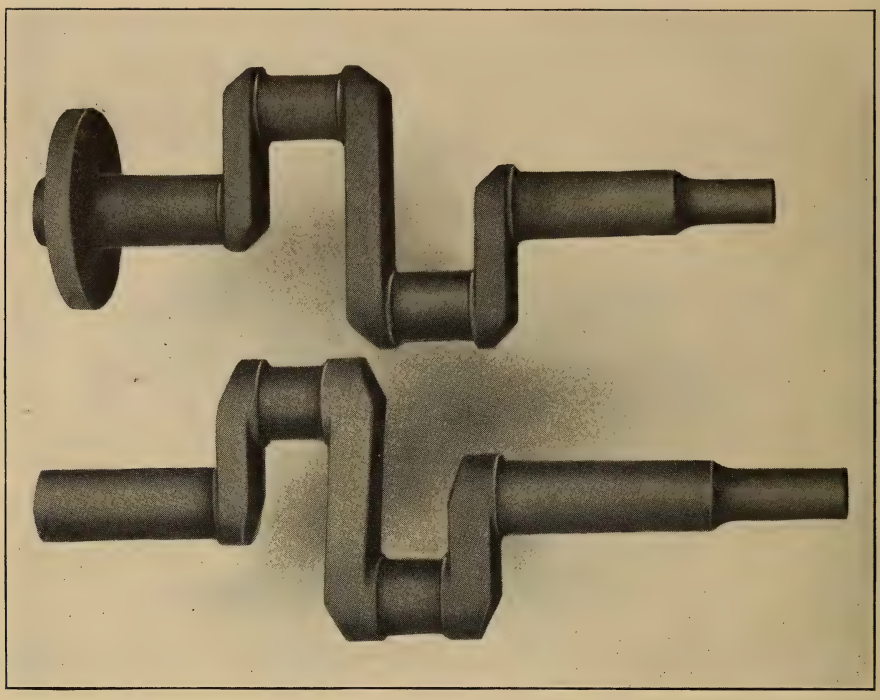
Such shafts were formerly forged in the form of flat slabs, the work being done under the steam hammer and the throws of the cranks being sawed or drilled out afterwards, leaving the crank-pins and the bearings in a square form, to be turned up afterwards. The cost and delays involved in this method have rendered it desirable to make such forgings by some more rapid operation, giving results closer to the finished dimensions and reducing the time required in the lathe.

One of the facts developed when it was first attempted to make these parts as drop forgings was that the high temperature necessary to render the steel sufficiently ductile to fill the impression of the die block caused the structure of the metal to become very open, with a low ratio of elastic limit to ultimate tensile strength. Many of the first shafts thus made failed in service, and serious prejudice was thus created among users against drop-forged crankshafts. Manufacturers experienced in drop-forged work, however, had overcome this difficulty in other and similar work, and realized that proper heat treatment was all that was necessary to secure forgings of satisfactory strength and elasticity. As a matter of fact, a drop-forged shaft which has been subjected to proper heat treatment is really superior to a slabbed forging which has not been thus treated.

The reason for the general absence of use of the heat-treating operation in the slabbed shaft lay in the fact that, in its natural condition, as it came from the hammer, it was in much better shape, so far as its structure was concerned, than in the case of the drop-forged shaft which had not been treated. This was due to the fact that the hammering, to which it had been subjected on an open die, could be performed at a sufficiently low heat, so that it was, to a large extent, hammer-refined.

It is possible, and is now common practice, however, to put a drop forging into far better condition than is the case in this hammer-refined state, and it is practicable to establish an elastic limit of between 80,000 and 90,000 pounds, in combination with an ultimate strength of 100,000 to 110,000 pounds, with from 18 per cent. to 20 per cent. elongation, in a good grade of open-hearth steel of 0.40 carbon. The production of drop-forged cranks, however, is not limited to carbon steels, as large quantities of alloy steels are forged into this form, the standard analysis of these being about $3\frac{1}{2}$ per cent. of nickel, with carbon contents at about 0.30. This metal is much more susceptible to the heat-treating process than carbon, good practice being able to establish 100,000 to 110,000 pounds elastic limit, in combination with 120,000 pounds ultimate strength, with 18 per cent. to 20 per cent. elongation .

These high elastic limits and ulti-



DOUBLE CRANK-SHAFTS, WITH FLY-WHEEL DISC AND EXTENSION BEARINGS

mate strengths are very necessary when one considers the enormous amount of work which these comparatively light cranks are called upon to perform.

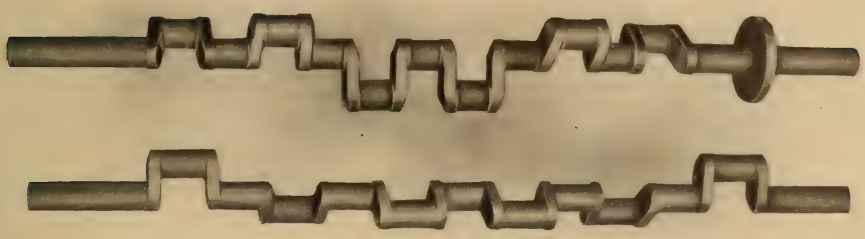
When one states that the transmission of 40 horse-power through a crankshaft $1\frac{3}{4}$ inches in diameter is common practice in automobile motors, he is talking in terms which would not be considered worthy of credence by any designers of the older school of steam engineering, and, in fact, would not have been believed even by the more advanced of those engaged in gas engine practice a few years ago.

A millwright would be considered as lacking in the rudiments of his profession who would attempt to transmit 75 to 90 horse-power through a line shaft not exceeding $1\frac{7}{8}$ inches in diameter, and yet this is being done successfully, and is considered as nothing at all out of common in automobile designing to-day.

The chief superiority of the nickel steel above the untreated carbon steel lies in the fact that, properly treated, the ratio of elastic limit to ultimate strength runs higher, a ratio of 75 per cent. being about the maximum in the carbon steel and 90 per cent. being obtainable in the nickel steel.

There are other alloy steels, which have been used somewhat in the making of these pieces, but to no great extent as yet, although, without doubt, the near future will see a large proportion of this article being made from a vanadium steel, containing about 1 per cent. of chrome and from 0.15 to 0.25 vanadium in combination with 0.25 to 0.30 carbon.

As will be seen in the illustrations, there is a great diversity of design in these shafts, as they are used in single-cylinder, four-cycle engines, two-cylinder of both the two and four-cycle type, the three-cylinder being confined almost exclusively to the two-cycle type, the four and six-cylinder



MULTIPLE CRANK-SHAFT DROP FORGINGS

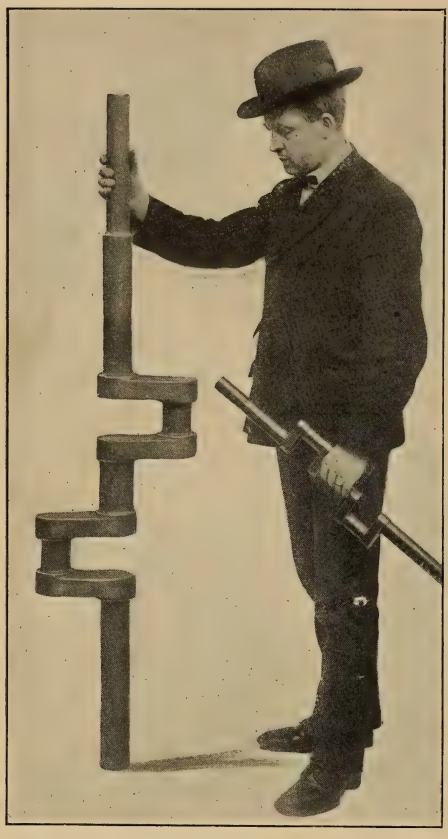
being, on their part, confined almost entirely to the four-cycle type of engine.

The four-cylinder shaft is the type of which the larger quantities are made, and their main diversity of design consists of the number of bearings, one style being a three-bearing and the other a five-bearing shaft; some of them have a flange at one end, used for the bolting on of the fly-wheel, and in combination with these a number of the makers use an extension beyond the flange for an outside bearing.

In the three-bearing style some designers use the slanting web, or arm, connecting the two outside bearings on each end of the shaft, and others increase the length of the two pins at this point to such an extent as to enable them to cross from the one pin to the other on a line at right angles to the axis of the shaft, this extension of pin generally being enlarged sufficiently to enable them to strengthen it and, at the same time, get a shoulder for the connecting-rod.

The use of ball bearings on these shafts seems to be coming into quite

EXAMPLES SHOWING PRACTICAL DROP FORGINGS FOR AUTOMOBILE ENGINES



DROP-FORGED CRANK-SHAFTS. THE LARGE ONE WEIGHS 185½ POUNDS; THE SMALL ONE 15½

general use, in which case the pins are shortened considerably.

Six-throw shafts are universally designed to have three pairs, of two pins each, these three pairs setting at an angle of 120 deg. with each other. These show the same diversity of design as regards the eliminating of some of the bearings upon adjacent pins as is the case in the four-throw.

It is quite common for the designer, in the case of the six-throw shafts, to run the slanting web from one pin direct to the other without first coming back to the centre of the shaft. This would show, in an end view of the shaft, a web running between two points, set out from the centre to the extent of the throw of the shaft, and spaced 120 deg. on a circle, the diameter of the travel of the centre of the pin.

This requires some nice calculation in the designing of the shaft, so that when twisted to the proper angles the web should be of exactly the right length to establish the proper angles.

Many users of shafts under-estimate the extent to which the drop-forging process has been developed to meet the requirements in this line.

As will be seen in the illustrations, shafts of quite an appreciable size have been produced by this method, the shaft shown in one of the photographs weighing approximately 190 pounds. This, while of fair size for a drop-forged shaft, is, of course, insignificant as compared with shafts used on some of the larger power units of gas engines which are being built for rolling mill work to-day.

The cost of the forged shaft is necessarily somewhat higher in the rough than those made by the slabbing process, but a comparison of the cost of finishing the two brings the total cost of the finished shaft strongly in favour of the drop-forged crank.

As one can readily see, the finishing operation, considered on the basis of the slabbed shaft, is very expensive, whereas in the case of the drop-forged article one can reduce it materially because of the fact that the shaft is forged so close to size that no finishing is necessary on the cheeks or arms, unless one wishes to do so for the sake of the appearance, and the amount of allowance for finish on the pins and bearings can be reduced to a $\frac{1}{8}$-inch chip in the case of a shaft having a pin or bearing the diameter of 2 to 3 inches. In fact, it is becoming very common practice to do no rough turning whatever on the drop-forged crank, it being first rough ground, close to size, and then receiving the finishing operation of grinding.

The production of these parts indicates the extensive use to which the gasoline motor is being put, one firm alone having forged 50,000 to 60,000 of these pieces, in the various sizes, during the last year.

THE USE OF WATER AND STEAM IN INTERNAL-COMBUSTION ENGINES

By Henry Henderson

ATTEMPTS at the use of water and steam in internal combustion engines were made years ago: Barber, in 1790; Street, in 1794; Lebon, in 1801; Brown, in 1823; Barnett, in 1838; Johnson, in 1841. This group of earliest inventors, starting with Barber, all aimed at the same object, that is, the employment of water for cooling purposes, and thus to increase the volume of the charge by generating steam at explosive temperatures and pressures. This principle was also used to increase the vacuum and to cool gases after combustion, obtaining higher compression, which insured greater efficiency and economy.

Owing to the many mechanical defects and abortive attempts to properly govern and control, the above early engines were not decided commercial successes: it was not until Lenoir, in 1861, brought out his engine that internal combustion motors received much attention, although some few of the earlier makes were run with partial success, especially is it so of the Brown engine. While the earlier types were not mechanically perfect, yet the ideas advanced and the media thought and sought for, were the commencement of what is to-day an important refinement in explosive or internal combustion engine practice at this date.

This statement is fully substantiated by the number of leading builders in the United States and Europe adopting similar methods and practices as those advanced a hundred years ago. Chemical actions of gases are the same now as they were then, and the success of present-day practices is due alone to a better understanding of how to confine, compress and control them, rather than in any startling revolutionary ideas mechanically or chemically advanced.

Modern tools and equipment, modern methods, modern organization all play their part in the successful manufacturing and marketing of the internal-combustion motor of to-day.

Returning to the invention of Lenoir, in 1861, which device was the really first recognized engine having any commercial value up to that time—he proposed to inject a little steam or water spray in the cylinder at the same time that the air and gas enter, and remain in the cylinder in regular strata and layers, the water spray taking up part of the heat generated by the explosion, and by evaporation aiding in the explosion, at the same time keeping the working parts cool and acting as a lubricant; the pressure of the steam greatly assisting the chemical combination of the explosive gaseous mixture, also avoiding sudden explosions, obtaining gradual combustion and higher compression, improving the economy, thereby increasing the efficiency of the engine. These engines were built in London in large quantities by the Reading Iron Works and many of them are still in use, pumping water after fifty years continuous service. Hugon, in 1865, next advanced the ideas of Lenoir and built engines of this type, adding several improvements in the way of hot tube ignition, instead of the less reliable electric spark and its accompanying short circuit and grounds. Hugon made the same claims for the

use of water injections as did his predecessor, and trial tests of his engines showed a marked economy in the amount of oil used per brake horse-power, the engines running most smoothly even with attending full or overloads.

Brayton, in 1878, brought out his oil engine, which was built by Simon & Son, Nottingham, England. This engine was of the constant pressure type, with the auxiliary feature of an evaporating attachment for utilizing some of the waste heat, steam to be used in the cylinder for the double purpose of helping drive the piston by its expansion, and at the same time assist in the lubrication and cooling, as well as cleaning of the cylinder. Here, again, the complications of the device caused its abandonment, as did the regenerative engine of Sir William Siemens, and the gas and steam engine combined of Chatterton in 1892. From then, up to the year 1900, nothing of any moment in engine circles occurred, excepting the introduction of the Vogt water piston engine, which bids fair in the near future to exceed in kinetic efficiency any engine of its type. The methods employed for the use of water, both for cooling and mixing, are novel and daring, and this type of engine absolutely substantiates the theories of a hundred years ago, or more forcible, as in this engine the entire area of the cylinder is filled with water, leaving only enough space for combustion and clearance purposes. Constant compression and space are possible and the results are remarkable: Water acts as a cushion between the piston and the explosion. Such an engine offers many advantages, and at once disposes of the heating difficulties in the cylinder and piston, and along with other obvious good points makes the development of this engine one of great comfort, and it will be watched with great interest, as this type of engine bids fair to excel anything yet promoted.

The Griffin hydro-oil engine, as manufactured by Dick, Kerr & Co., London, is one of the best modern types of engine brought out. Much importance is attached by the makers of this ingenious engine to the treatment of the oil in the cylinder; if the temperature in the vaporizer is too high, the oil will be gasified. Cracking takes place and tarry products which are difficult to burn are formed, therefore when the exhaust opens, combustion is often incomplete. To avoid these difficulties and to insure the perfect vaporization of the oil at a relatively moderate temperature, they have brought out the above type of engine with the addition of the old Lenoir idea of a small quantity of water being added to the oil. A charge of oil and water is atomized and thoroughly mixed by a blast of air at a pressure of 15 pounds; here it is further mixed with air heated by the exhaust—the same pump supplies oil, water and air. The suction stroke opens the air valve to the atmosphere, the current of air lifts the oil and water valves and instantly converts them into mist. With this system of vaporization, combustion is said to be complete and no deposit is left in the cylinder, the charges are virtually water gas, its big percentage of hydrogen increases the volume and forces of the mixture, thereby increasing the efficiency of the engine. It is most interesting to observe the immediate effect of diluting the charge with water spray. The engine quiets down and runs smoothly without shock or vibration, the explosions being slowed until it becomes simply combustion; combustion, however, which leaves no solid product in the cylinder, the steam generated compensating, by its volume, for the reduction of temperature which its formation causes in the exploding mixture. During combustion in the cylinder the water vapour is decomposed and burned in combination with the oil vapour; the added heat of the burning water gas seems to effect the complete combustion of the whole of the heavy hydrocarbons

of the oil: perfect combustion, absolute cleanliness and great economy are thus obtained; tube ignition is both simple and effective, mis-fire being impossible under any conditions.

The Priestman engine uses a water injection in connection with sprayers, vaporizers, etc., and when the engine is working at full load the steadiness in running is greatly improved by the injection of a few drops of water in the combustion chamber during admission of the charge. The water injection reduces the hard metallic knocks or blows of heavy and sudden explosions at full load. The water is converted into steam and reduces the temperature of the charge, making possible a reduction of clearance with increased compression, without fear of premature ignition; the higher explosive pressures are reduced and the mean effective pressures are better sustained, lubrication is assisted, cleans the piston and cylinder surfaces, showing that condensation of the oil vapours are encouraged.

The Gothic oil engine, built by Messrs. T. Glover & Co., is an oil engine with a condenser and cooler built in the bottom of the crank-case; the water is heated by the exhaust gases and is kept about one-half inch deep. It is obvious that as the hot gases expand and part with their heat to the condenser, the temperature of the surface of the water rises and gives off water vapour, or wet steam; this is driven into the steam dome attached to the cylinder head; it is here condensed as water, and mixing, is driven with the oil into the vapourizer, entering the cylinder with the proper amount of air, it serves the useful purpose of prolonging combustion.

The Simplex, built in France in 1890, by M. M. Delamere, is the same as the now famous Dutz engine, which is built by the Société Cockerill, Belgium; it is also built in England by the Messrs. Richardson & Westgate. The Simplex carburetor is used on some of the sizes, and consists of a base containing water, a hollow shaft arising from same, which in turn supports the oil tank, the hot jacket water flows into said shaft, meeting a stream of oil which runs down the enclosed taffels, made of spiral brushes into the tank below. The suction stroke of the engine draws air through the oil and water vapour from the tank where it is charged and is then drawn into the cylinder.

The Dutz engine is now being experimented with by the General Electric Company. Mietz & Weiss, of New York, are now putting on the market their new oil engine. The new feature in connection with same is the use in the cylinder of the steam generated in the water jacket, which is different from all other explosive motors in principle and effect; it utilizes a large part of the heat ordinarily lost through the cylinder walls and cooling water, and considerably reduces the trouble of decomposition of carbon in the cylinder, probably by the deseccation of the water vapour furnishing oxygen to the hot particles of carbon; the air and water are compressed, the oil is admitted and exploded, and by its heat deseccates the steam, which adds further elements of combustion to the unconsumed carbon; this increases the mean pressure of the expansion curve. An efficiency for the steam, air and oil mixture of 15 to 20 per cent. is claimed, higher than for the oil and air mixture alone, the total thermal efficiency in several tests being 44 per cent., with a compression pressure of 100 pounds and 170 pounds explosive pressure, using one pint of oil per brake horse-power-hour.

Crossley Bros., England, have lately adopted the water spray for both their gas and oil engines made in England. From tests lately made, the marked increase of thermal efficiency shows at a glance the great advantages to be obtained by use of the water spray; the efficiencies obtained were the highest of any make

yet, adopting the water spray. An eminent English engineer made some tests in November, 1905, with most flattering results; he says, in part: "Up to the present time, when using coal or producer gas, the compression has been limited to about 110 pounds. Compressions higher than this are apt to heat up the charge to such an extent as to cause premature ignition, that is, the charge ignites before the end of the compression stroke. In the new engine, compression is carried to over 200 pounds, and in which premature explosions are prevented by drawing in a small quantity of water during the suction stroke. The engine ran smoothly without back explosions. The clearance and volume was 0.243 cubic foot, the cylinder volume was 1.782 cubic feet, and the ratio of expansions 8.7, the maximum pressure in the cylinder was 528 pounds above atmosphere, the volume at maximum temperature being 0.247 cubic foot, the adjoining pressure during suction stroke of piston was 1.9 per square inch below that of the atmosphere; the compression curve equals 6.508 pounds, and the expansion curve 17.610 pounds. During the suction stroke the injected water appears to be turned into steam, which becomes superheated during compression. Heat passes into the charge from the walls until a pressure of about 100 pounds is reached, when the charge appears to be as hot as the walls; the heat additions prove that the whole of the available heat, that is, the total heat of the charge, less that rejected into the water jacket, has appeared at the point of maximum temperature; taking the total heat of the gas used per explosion at 100, the indicated work is 37.4; heat rejected in water jacket 29; in exhaust 33.6. The percentage of useful work is the highest thermal efficiency which has been obtained in any test."

Banki petroleum and alcohol engine, made by Ganz & Co., Vienna and Buda Pesth, has had the greatest sale of any engine made in Austria; it is especially adapted for agricultural purposes. The main features are the water injections, oil and air pulverizers, high compression, small clearance, great efficiency and economy. Proceeding on the now well established fact that the true means of increasing the efficiency of an engine is to be sought in greater compression of the charge, Banki justly observes that as compression is increased, the temperature of the explosive mixture will be raised, and more trouble will be caused by premature ignition. To avoid this difficulty, the air and combustible must be separately compressed, or the oil admitted only after compression. Another way which, according to Banki, increases, instead of diminishing, the efficiency is to cool the charge itself; and this he has done by a novel method of water injection. Hitherto, the injection of water into the cylinder of an internal combustion engine has not greatly been very advantageous, because the object was to increase the pressure by evaporation, and not by reducing the temperature. To obtain higher compression in the Banki system the water is introduced in a very fine spray and thoroughly mixed with the oil and air, in accordance with the conditions; the lamp has been dispensed with after the engine has started, the heat generated by the motor itself being sufficient for the vaporization and ignition of the oil, thus, automatic action greatly conduces to the efficiency of the engine. This system was tested by Professor Banki, at M. M. Ganz' works, and the four-cycle engine ran well and quietly, although the compression space was greatly reduced; but when the water was shut off there were violent explosions. The consumption of oil was much less with the water injections. The air and pulverized water and oil are compressed to 13 atmospheres, the heat of compression evaporating the water, and combustion produces superheated steam at

30 atmospheres pressure, which, by its expansion, increases the work done. The engine only consumed .45 pound per brake horse-power-hour with a mean pressure of 10 atmospheres; the kinetic efficiency was from 25 to 30 per cent. This most striking result was entirely due to the water injections, which allow of much higher compression, which means greater efficiency—the larger sizes even show as high as 35 per cent.

The German Motor Construction Company, of Marionfeld, from test made by Professor Musil, of Berlin, show the efficiency of motors using water mixtures to be as 13 to 28 or over 50 per cent. greater efficiency. The higher efficiency is eventually due to the great elasticity derived from the expansion of the water vapour that is contained or produced by the mix at the moment of its combustion, this expansion tending to make the explosions in the cylinder less violent than when the water addition was not used, thereby giving longer life to the machine. So much has this been found to be the case that in order to increase the beneficial action of the water vapour, the above company recommend a mixture of 20 per cent. water in addition to the alcohol, or alcohol or gasoline mix employed. And it has built motors to run on such mixes that consume only .17 pound per brake horse-power-hour, establishing a precedent for makers in this country, that they have so far been unable to attain. Alcohol motors just brought out in France, called the economic (especially constructed), show the very remarkable small consumption of .12 pound per brake horsepower-hour, using a mix of 50 per cent. water. For stationary purposes the problem has been solved. Engines of this type should have the stroke double the bore; high compression and a good spark.

Quoting again from Kennedy, who says: "The drawing in some water spray with the oil does seem to offer very considerable advantages, as we have already shown and explained in connection with the various makes of modern engines now employing this method for increasing efficiencies;" the effect is two-fold, increasing power and economy, which means success commercially, which in turn means high mechanical and thermal efficiency. In theory the consumption of spirits for an equal power is 1.8 times the consumption of oil. In practice, however, the presence of water in the spirits increases the elasticity and efficiency of the mix, and the proportion is only 1.25 to 1. The water in spirit motors makes them run more smoothly with more elasticity than petroleum motors using none.

The pressure of explosives can be increased without disadvantage to the machine, the expansion curves being very regular. The efficiency of these water-injected or water-mixed motors is 25 to 30 per cent., against 15 to 18 for oil motors without water injection.

In Captain Longridge's paper, read before the Mechanical Engineers, 1902, he gives M. C. Rainey's conclusions on the point thus from the experiment made:

1. That while maintaining the oil supply constant, the addition of water gave increased power and greater economy.

2. This effect was maintained until the water reached a quantity equal to the amount of oil.

3. That a greater amount of water interfered with the sparking.

Up to the present time no complete explanation of these better results has so far been published. The advantages of water have been decided as a contribution of mechanical energy in the form of steam. As a cooling agent obtaining increased charge volume and giving higher compressions by absorbing the violence of explosions, by allowing smaller clearances and by rendering premature ignition less liable, these virtues in oil engines are of such

importance that it will take considerable theory to disapprove the advantages and value of same. During a recent testing with tube ignition of an oil motor, admitting moisture to the combustion chamber, a sudden advance in ignition was observed, together with an increase of exhaust temperature, leading to a burning of the valves. The following may be the possible reason: assuming the cylinder charge to be pentine (C_5H_2) the addition of water or aqueous vapour in contact with the incandescent tube might lead to partial decomposition, carbon combining to carbon monoxide, hydrogen being liberated; in other words, water gas would be formed, the advance in ignition would be due to the greater inflammability of the gas, and may be established thus, the molecular weight of pentane being 12, 256 of oil would be required for perfect combustion; on the other hand, the molecular weight of the water gas ($CO + H_2$) being 32, the oxygen needed for complete combustion would be 48; one part by weight therefore would equal 3.51 O. and one part of water gas 1.5 O.; this at once shows why the ignition is advanced, the inflammability of the water gas being due to the lesser amount of oxygen wanted for combustion. The increased temperature of the exhaust might be accounted for by assuming that the water gas burned with a fierce heat and acted as an extended flame carrier, producing more rapid and complete combustion of the charge. In conclusion, the phenomena of earlier ignition and hotter exhaust when a little water is present, with increased power and cooler running when a large and regular supply is added, needs another explanation. The advantages of water injection lie only in the possibility it gives of employing much higher compression without risk of premature ignition, of obtaining heavier charges and of reducing heat loss through cylinder walls. Whatever may be the real action of the water, its advantages are beyond question, and it is being universally and generally adopted. If, as Professor Hutton, of Columbia University, says, the use of water in the cylinder of internal combustion engines is a charge on the wrong side of the ledger, why then do all the suction gas producer manufacturers use water or steam in their combustible charge for engines? Why is it that all the fast oil burners use steam in the generation of gases? It is to get the benefit of the hydrogen, to increase the volume and elasticity of the engine charge and to raise the value of the British thermal units in the burner spray. The only piece of mechanism about a suction gas producer is the means employed to generate steam and vaporization of water. In ordinary practice about one-quarter gallon, or $27\frac{1}{2}$ pounds per horse-power-hour, is necessary for use in the vaporizer; this, of course, does not all reach the engine cylinder. The general analysis of water gas would be as follows, made from anthracite of 14.256 British thermal units,

PRODUCTS OF HEAT AND POWER	
Hydrogen, parts by volume H	242
Monoxide of C., parts by volume CO	166
Methane, parts by volume CH_4	20
USELESS	428
Carbonic acid, parts by volume CO_2	113
Nitrogen, parts by volume N	459
	1,000

55 per cent of the heat and power properties of the charge would be hydrogen, derived from the water vaporization.

Quoting Professor Meyer, of Charlottenberg, Germany, he says, in continuance, "from this it would seem that the higher efficiency of the alcohol motor is due almost entirely to the high compression which can be used. How comes it, then, says Kennedy, that this compression can be used in case of alcohol, and not in the case of petrol or other oils?" During the compression of a mixture of our fuel as vapour and air, heat is given out, and at a certain point the temperature attained by the mixture is such that explosion takes

place. This point of automatic explosion fixes the absolute limit of compression which can be used. If the compression be carried beyond this point, we get what is known as premature ignition, that is, an explosion before the piston has reached the end of the compression stroke. Now, the temperature which a mixture of gases attains upon compression depends largely upon the specific heat of the substance in the mixture. In the case of oils this is very low, in the case of alcohol it is very much higher, and we have also to bear in mind that the spirit used in these experiments contained 10 per cent. of its volume of water. That the influence of water is to allow of a very much higher compression is shown in the case of the Griffen motor, where, by the injection of water along with the charge, compression of over 10 atmospheres were attained with safety; whereas, without the water, from four to five atmospheres is the permissible safe limit. A still more striking testimony as to the influence of water vapour in reducing the ignition point of explosive mixture of gases is shown in the case of the new Vogt engine, where, using coal gas and air in the presence of steam, it was found necessary to produce compression pressures of 25 atmospheres before self-ignition took place.

A study of Professor Meyer's work certainly leads to the conclusion that the increased efficiency of motors using water or steam in the mix is entirely due to the increased compression employed, and the possibility of employing this compression is due, in the first place, to the low inflammability of alcohol air mixture; but in the second place, and in a higher degree, to the water contained in the mix. The question might be raised, why not use more water and a higher compression? This has been tried, and Mr. Exner, of Vienna, has been able to prove that by so doing there is an increased efficiency; further water, however, without a corresponding increase in compression, has a disadvantageous effect.

By increasing the compression we may use a mixture containing an increased percentage of water, and at the same time obtain better useful effect from the fuel, but the percentage of gain which is obtained from compression beyond 12 or 15 atmospheres is so small that the uncertainty of ignition, added expense of construction to withstand the accompanying high maximum explosive pressure more than counterbalances it. Of the ten motors entered for competition, Professor Meyer found that the one that worked the poorest mixture with the most economical results would require the ingoing air to the vaporizer to be heated to a temperature of 125 degrees in order to carry the oil and water in the form of vapour.

The obvious method of cooling the cylinder by injecting a spray of water directly into the interior, was employed in the early machines, this having been used in the Lenoir engine as long ago as 1860, and by many others since. The advantages and disadvantages of this method of cooling the cylinder of an internal combustion engine are discussed very fully in a paper by Dr. K. Schreber, in a recent issue of the "Revue Générale des Sciences," and some valuable points brought out for practical use.

It is assumed that when a spray of water is injected into a highly heated cylinder the water will be immediately vaporized, this acting to lower the temperature, and at the same time convert the heat into mechanical energy, acting through the expansion of the steam upon the piston. While this action does take place, it is found in practice, as Dr. Schreber shows theoretically should be the case, that the efficiency of the engine is lowered by the injection of water, as practiced by Lenoir and his imitators.

The energy developed by the va-

porized water is abstracted from that of the expanding gases, and the total result is inferior to that which would obtain if the water were not used.

At the same time, the injection of the water has been found effective in protecting the cylinder from becoming overheated, although in practice it is generally used in connection with an external circulation in a water jacket.

During the past few years, however, there has been designed an internal combustion engine, known as the Banki motor, the invention of Professor Banki, of Budapest, in which the vapor of water is used in the cylinder, and which, apparently contrary to theory, has shown a very high thermal efficiency. Dr. Schreber examines the action of this engine, and shows clearly the reason for its efficiency, and incidentally throws much light upon the action of such motors.

It is well understood that in internal combustion motors a high degree of preliminary compression is necessary in order that a high efficiency be obtained. The charge drawn into the cylinder must be highly compressed on the return stroke before ignition takes place, and the higher this compression pressure the better the efficiency.

The ordinary limit to high compression is the temperature of ignition of the explosive or combustible charge. The compression produces heat, and, with the usual charges of gas, or hydrogen vapour, and air it is easy to reach the ignition temperature by compressions lower than would otherwise be advantageous.

The premature ignitions thus produced are objectionable and even dangerous and cannot be permitted, so that a lower degree of compression is necessarily employed than is desirable. In the case of the Diesel motor the air is compressed alone, so that there is no limit to the degree of compression by reason of any fear of ignition, the liquid fuel being injected only at the beginning of the stroke and the heat of compression being used as a means of ignition.

In the Banki motor a fine spray of water is injected into the mixed charge of air and hydrocarbon vapour in the suction pipe, and vapourized by the heat of compression, the absorption of heat thus effected enabling a high degree of combustion to be used with safety. The economy due to the high compression overbalances the loss produced by the moisture, and the net gain is sufficient to account for the high efficiency of the motor.

Dr. Schreber examines the conditions of operation in the Banki motor, and shows that, even with the arrangement there adopted, the addition of the water is not effected to the best advantage.

Theory indicates that in any case the cooling effect should be produced with the least possible proportion of moisture. With the injection of a water spray into the suction, a portion of the water necessarily gathers in the form of drops upon the walls of the cylinder as the piston advances, and these drops are not vapourized until the explosion occurs when the heat of the combustion and the enhanced temperature of the cylinder walls complete the evaporation. This action, as already mentioned, diminishes the efficiency of the engine, to the same extent as if the water had been injected during the expansion, and to this extent the Banki system is defective.

Dr. Schreber proceeds to discuss the principles upon which water injection may be used to the best advantage. Assuming that the real object of the water is to keep down the compression temperature and thus permit a high degree of compression, it is important that the quantity of water should be kept at a minimuum, and that it should all be vapourized during the compression. It is important that the injection should not take place until the temperature of the compression reaches that of the vapourization of the injected

liquid at the corresponding pressure. At the end of the stroke there should be a slight excess of temperature in order that the vapourization should be completed, this insuring the absence of any liquid drops to abstract heat from the ensuing combustion.

This sequence of events may be regulated by experience, data for computation being as yet uncertain.

Thus far the injection of water alone has been considered, but the idea may be continued further. If, instead of gas, or vapour of hydrocarbon not miscible with water, we use a fuel, such as alcohol, with which water may be mingled in all proportions, it is possible to extend the principle. Dr. Schreber discusses the action of a two-cycle motor, but the principle holds good for either a two-cycle or a four-cycle engine. The charge of pure air is compressed until the compression temperature exceeds that of vapourization of the alcohol fuel, at which moment the alcohol is injected and vapourized together with its contained water. The degree of compression desired may be controlled by the proportion of water, this being kept as low as possible consistent with the prevention of premature ignition.

At the end of the stroke the charge is then ignited in the usual manner and the cycle is completed. It will be seen that this differs from the Diesel motor in that the liquid fuel with its contained water is not ignited by the compression, but merely vapourized, although the action resembles that of Diesel in giving the air a preliminary compression before the fuel is injected. The method appears to eliminate one of the difficulties heretofore existing in alcohol motors, that of the carburetor, since the carburetor is entirely replaced by the vapourizing action of the heat of compression. The degree of compression may not be carried so high as to reach the ignition point of the charge, but it can reach a much higher temperature than would be possible safely if the water were not present.

Dr. Schreber gives an elaborate thermodynamic discussion of an engine operating with a liquid fuel injected during the middle of the compression portion of the cycle, showing that an alcohol motor constructed on this principle should have distinct advantages, and it is to be hoped that such a motor may be given opportunity for practical trial and scientific test.

There is no doubt that alcohol may be used with success in the Diesel motor, and the whole field of internal combustion motor design appears to be open to the fuel which is being liberated by relief from excessive taxation.

* * * *

While the primary object in compiling this article was to simply show the ideas and methods adopted by past and present inventors and manufacturers in their use of the water spray for internal combustion engines, it may not be amiss to say, in conclusion, that commercially the outlook for an engine of this type is particularly bright. While the 180 odd manufacturers of gas and gasoline engines have partially covered the ground, the field, as a whole, is yet in a virgin state, and the engine that can use heavy oil, crude oil, alcohol, in fact any oil or spirits without serious adjustment being necessary, will command the trade. Up to the present time the competition has all been for the best, in the sense that it has stimulated invention and experiment and improvements have followed, which now, as the almost prohibitive price of gasoline, kerosene, naphthaline and the lighter distillates in general will, in part, debar all such classes of engines from the field; the crude oil and alcohol motors, with their modern refinements of adjustment and control, will take the permanent place they deserve for all industrial, marine and railway purposes.

MACHINE TOOLS FOR GAS ENGINE CONSTRUCTION

I.—RECENT BRITISH MACHINE TOOLS

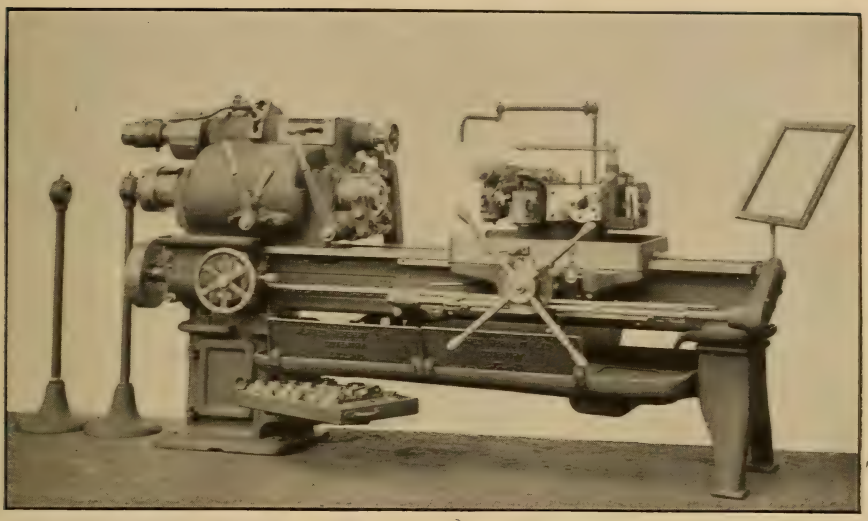
THE development of every department of manufacture has its influence upon the tools by which the special product is made. This influence is not felt at first, but as the manufacture is differentiated, and special repetitive processes come into service, existing machines are modified and new ones designed, until the specialization is carried as far as the conditions warrant.

The development of the various forms of the internal-combustion engine is no exception to this rule. The larger types of gas engine fall into the same general line as the steam engine of corresponding size and perfection, while at the same time there is a marked resemblance between the work upon the gas engine and the air compressor or the refrigerating machine. High pressures, marked differences in temperature and accurate mechanical movements all have to be provided for, and in general the same class of machine tools find favour. With the smaller combustion engines, such as those used so extensively in automobiles and now being designed for experimental work in aeronautics, the conditions are somewhat different, and the special nature of the tools becomes still more marked. Nevertheless, no one of these industries has yet reached a stage in which absolutely special tools are generally employed, and by far the greater number of machines used by the leading builders of internal-combustion engines are modifications of standard machine tools, with attachments, etc., developed from the special character of the work. We shall, therefore, illustrate in this, and the following article, some of the latest types of tools of standard builders in Europe and America, with especial reference to their use in gas engine manufacture, as indicating the lines along which further specialization is likely to proceed.

Since the manufacture of internal-combustion engines is a comparatively recent department of machine work, it is to be expected that modern methods will be found in such shops, and practically all of the tools shown in this connection are intended for use in connection with the modern rapid-cutting steels. Much of the work is done upon turret or capstan lathes, often semi-automatic in operation, with special tools, stops and controlling appliances, intended to permit of the repetition of operations and the economical production of accurately finished parts without absolute dependence upon the individual skill of the operator. Planing machines are adapted to the accurate finishing of surfaces at high speeds, while boring mills and drilling machines are equipped with movements fitting them to keep up with the general pace, and, as the illustrations show, the general design of machines intended for this work bear evidence of the skill and intelligence of the builders.

In the present article there are shown machines produced by a number of British establishments, and these will be followed by some typical American tools and their products.

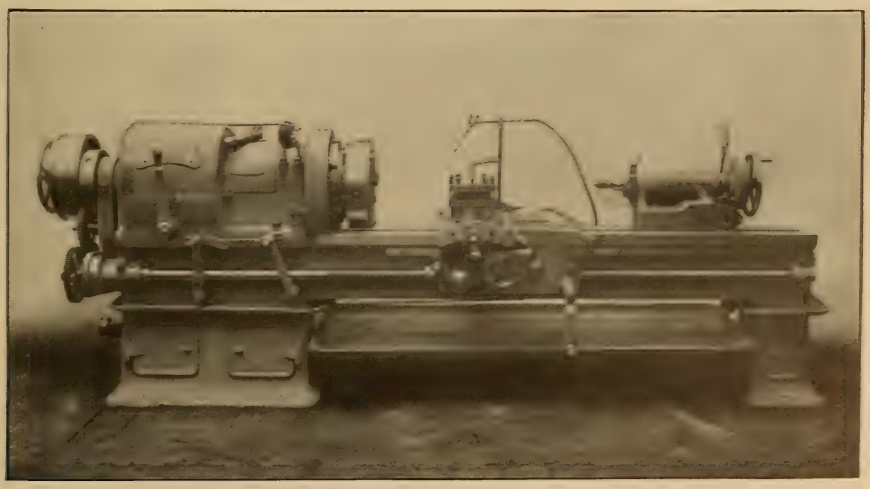
Among the turret lathes adapted for the use of builders of gas engines may be noted the hexagon turret lathe of Alfred Herbert, of Coventry and London, this machine being fitted with single pulley head, automatic chuck, dial feed and indi-



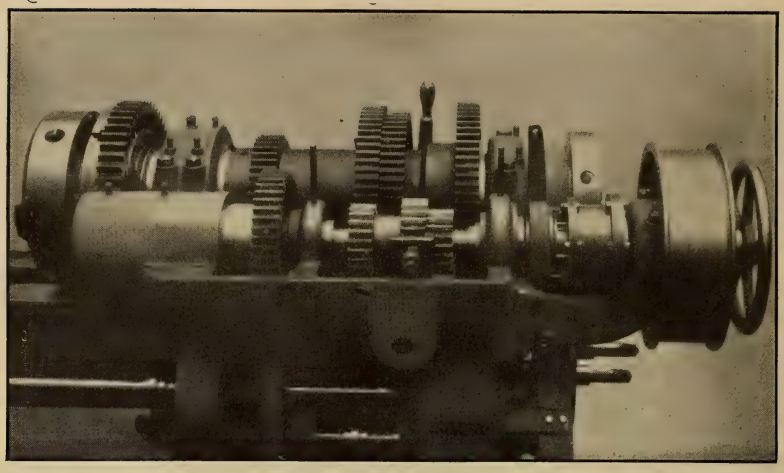
HEXAGON TURRET LATHE. ALFRED HERBERT, LTD., COVENTRY AND LONDON

cator, scale and pointer. This machine, as well as the capstan lathe of the same builder, is well adapted for dealing with valve spindles, cam shafts, etc., and the chucking lathe is used in making valves, pistons and piston rings for gas engines. With the use of high-speed steels and the corresponding feeds, Messrs. Herbert have introduced the roller steady tool shown in the illustration, by means of which the output of such machines has been increased some 400 per cent.

Modern speeds and feeds have led to the design of lathes in which the belt is run at a constant speed, the changes in speed being made by gears instead of cone pulleys. Such a machine, built by Messrs. J. Parkinson & Son, of Shipley, Yorkshire, is illustrated, together with a detail of the headstock, exhibiting the arrangement of the gearing. The sliding gears enable speeds from 10 to 300 revolutions per minute to be obtained, the lathe being started and



ALL-GEAR LATHE, 8½ IN. CENTRE. J. PARKINSON & SON, SHIPLEY ENGLAND

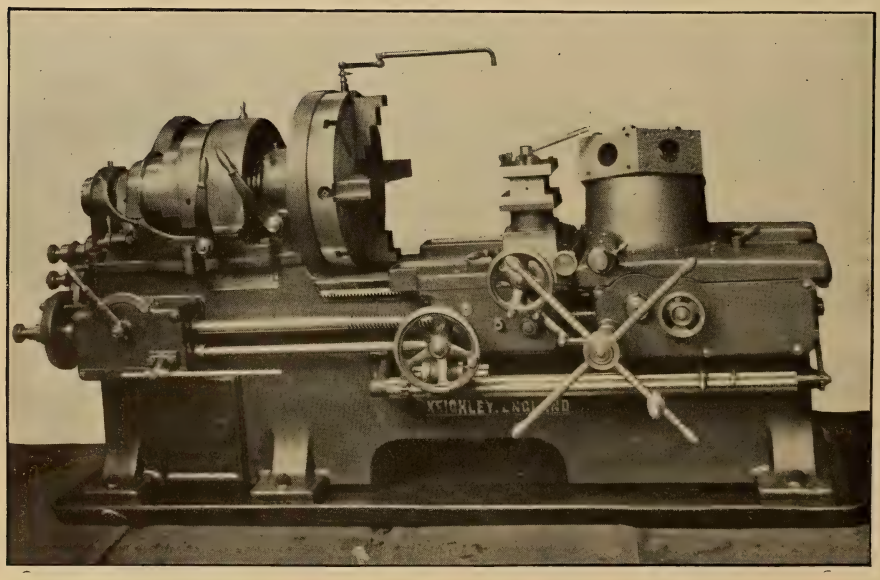


ARRANGEMENT OF GEARING IN HEAD OF PARKINSON LATHE

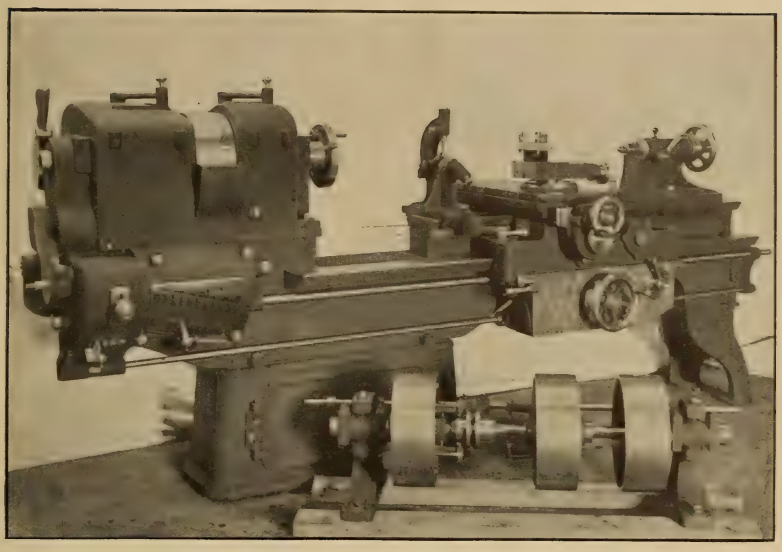
stopped by means of a friction clutch between the belt pulley and the first motion shaft of the headstock. The spindle is made with a hole 2 9/16 inches in diameter, to admit a $2\frac{1}{2}$-inch bar.

Among the larger machines may be noted the 24-inch swing surfacing and boring lathe of Messrs. Dean, Smith & Grace, Ltd., of Keighley. This is a powerful high-speed lathe, double and triple geared, the hole through the spindle admitting a bar $3\frac{1}{2}$ inches in diameter. It is provided with a hexagonal turret, as well as a supplementary saddle carrying a square turret, and the machine is especially designed to meet the demands of the combustion motor industry.

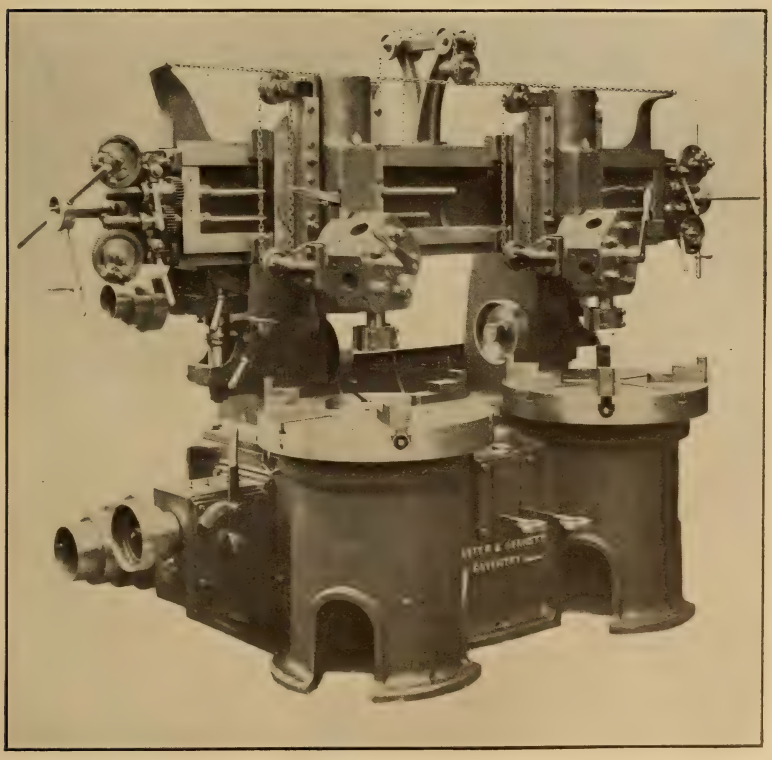
A lathe designed for similar service is built by John Lang & Sons, of Johnstone, near Glasgow. This machine also has both square and



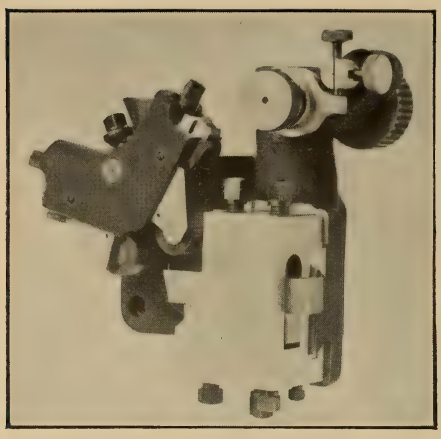
HIGH-SPEED SURFACING AND BORING LATHE. DEAN, SMITH & GRACE, LTD., KEIGHLEY, ENGLAND



SLIDING, SURFACING, BORING AND SCREW-CUTTING LATHE. DRUMMOND BROS., RYDE'S HILL, ENGLAND



DUPLEX VERTICAL BORING MACHINE. WEBSTER & BENNETT, COVENTRY, ENGLAND



ROLLER STEADY TOOL. ALFRED HERBERT, LTD., COVENTRY

hexagonal turrets, mounted on separate saddles, and has the special feature of a variable-speed drive on the headstock, constructed upon the principle of expanding and contracting friction cones, with special belt. This device enables the operator to obtain the correct surface speed for any diameter within the range of the lathe, the variation being controlled by a hand wheel placed conveniently to the workman, an index showing the speed at any time.

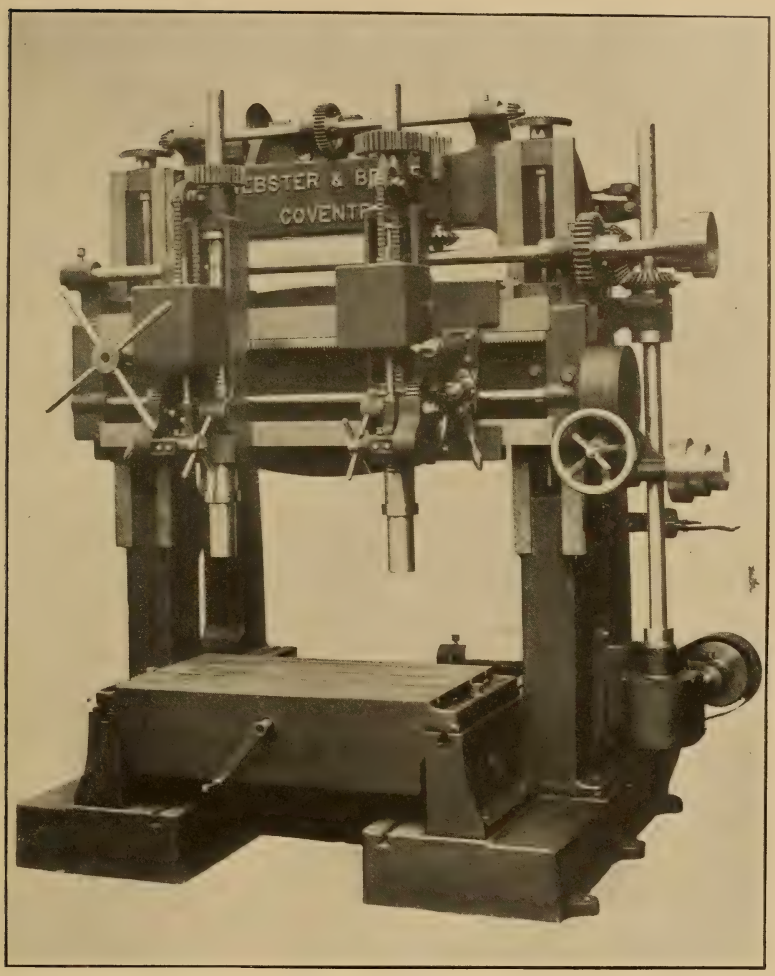
In the design of lathes for use with rapid-cutting steels it has been found that it was not sufficient to increase the belt power alone, as by increasing the dimensions of the cone, but that the whole machine had to be redesigned, with increased strength and stiffness, and with proper provison for receiving the work in accordance with modern high-speed methods.

A lathe involving these principles is illustrated in the machine built by Drummond & Bros., of Ryde's Hill, near Guildford, Surrey. Large machines have already been designed in full accordance with the requirements of high-speed work, and this lathe is constructed more nearly in the manner of a heavy tool than is usual in lathes of its size. The illustration is of a 9-inch lathe, with stiff box bed, the slide rails, on which the saddle is guided, being formed at the level of the bottom of the gap, extending right along the gap space, instead of being formed at the top level and stopping short of the gap space. This avoids the use of the undesirable and inconvenient gap piece. The compound rest slide practically forms a truly surfaced boring table, on which not only ordinary boring can be done, but holes parallel with each other in the same casting, this rendering it available for boring twin cylinders and similar motor work.

Larger boring is well effected upon the vertical boring mill, and an interesting machine for such work, especially in connection with gas engine manufacture, is found in the duplex vertical boring mill of Webster & Bennett, of Coventry.

Being a combination machine, one operator can attend to both tables. In the matter of output it scores heavily over the lathe on such work as pulleys, gear blanks, cams, piston rings, etc. This latter affords a very interesting example of its uses. The casting for producing piston rings consists of a deep, hollow cylinder, which is fastened to the face-plate or chuck. After taking a cut across the top of the casting, a special holder carrying two tools—one to cut on the inside and the other on the outside—is presented, and with this the cylinder is rough turned and bored for about 3 inches down. A similar arrangement with finishing tools completes the turning. The last operation is also with two tools, and these are for parting-off the rings, which may be five or six in number.

In dealing with the ordinary boring, this machine forms a valuable factor in the introduction of the limit gauge system. By using the proper sequence of roughing and sizing tools and finishing with adjustable reamers, holes are produced in the work which are straight, parallel and all of one size, and allows the shafts which fit in them to be finished to the micrometer without the nuisance of mak-



TWO-SPINDLE 2½-INCH DRILLING MACHINE. WEBSTER & BENNETT, COVENTRY

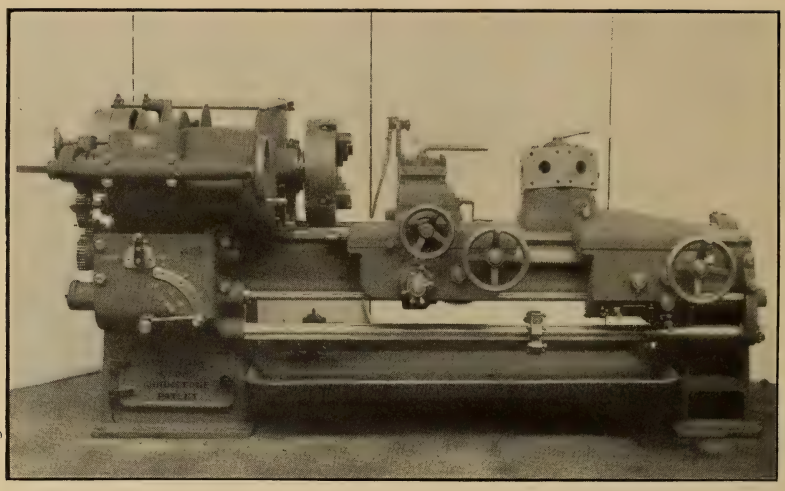
ing each shaft to meet its particular hole.

To meet the modern requirements of high-speed steel the machine itself is very massive in construction, weighing 5¾ tons.

Each chuck is 30 inches in diameter, has four jaws, and below them are the pressure rings running in oil, which take all the down thrust.

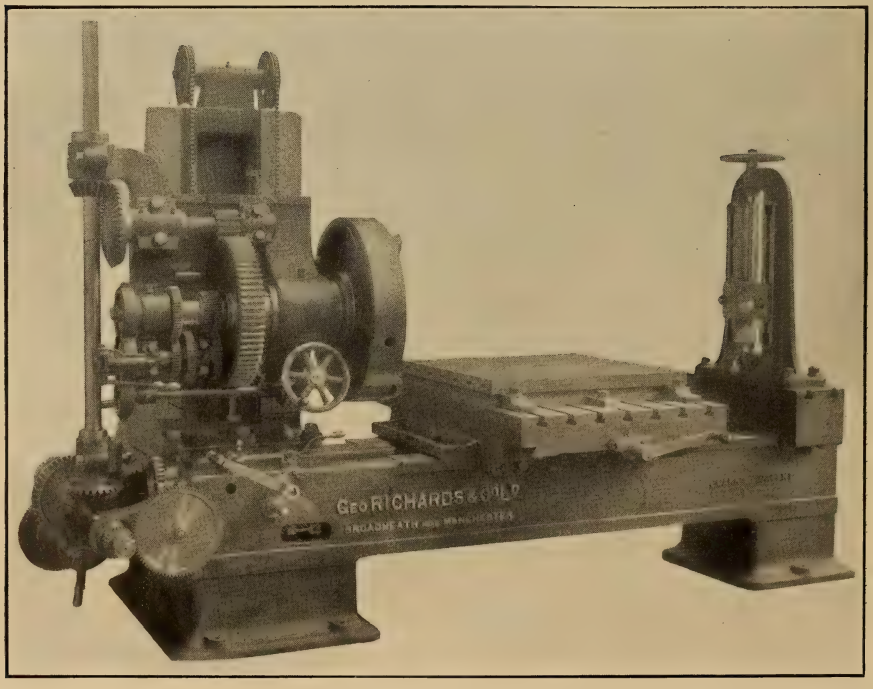
The turrets are pentagonal in form, for convenience in attaching special tools when desired. They are capable of an automatic angular as well as a vertical movement 18 inches in length to enable parallel and also taper work to be coped with. The cross movements are also self-acting, and a reversing motion controls each one. To enable the operator to concentrate his energies on keeping both tools cutting as much as possible, the slides are quickly manipulated by power, thus saving the usual labourious hand-work.

Messrs. Webster & Bennett also build a two-spindle drilling machine capable of dealing with work having holes more than 6 inches apart on one piece, or with two separate pieces at one time, the holes being up to 2½ inches in diameter. This ma-

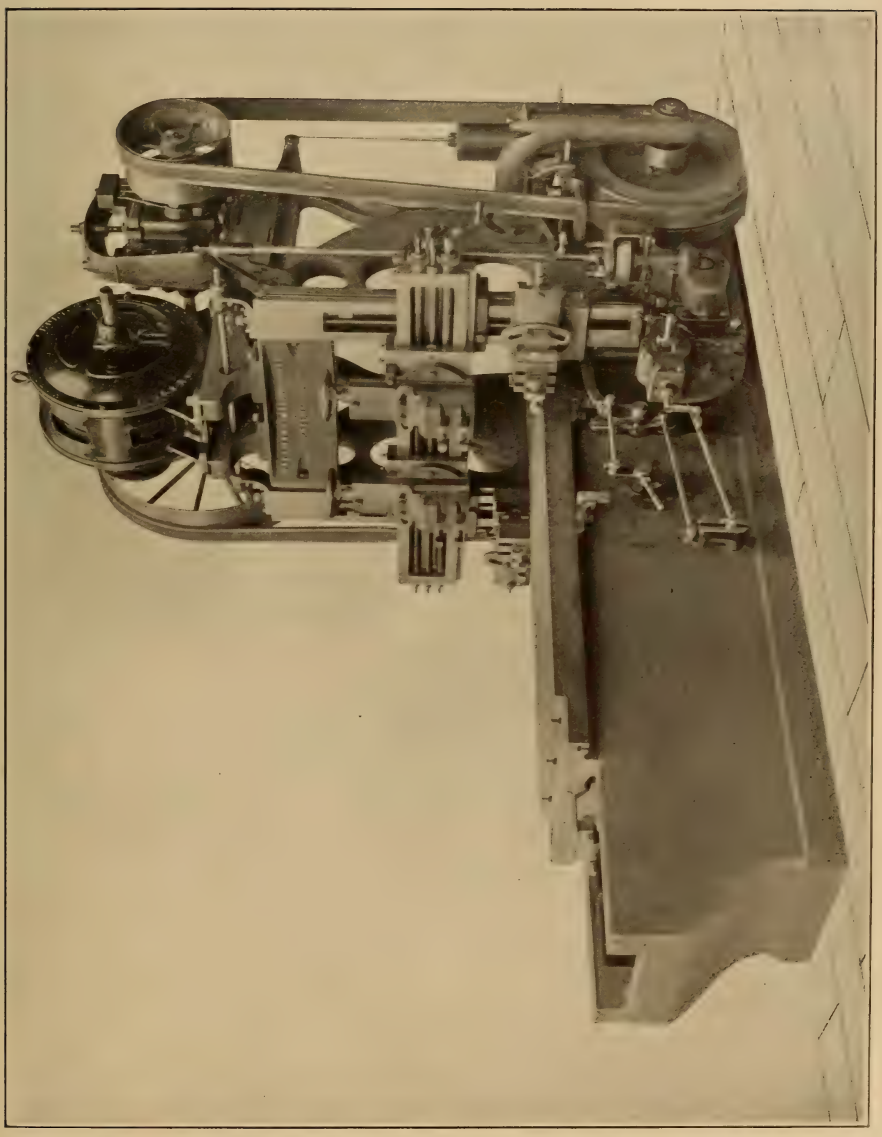


VARIABLE-SPEED HEADSTOCK SLIDING AND SURFACING LATHE WITH TWO SADDLES. THE FRONT SADDLE HAS SQUARE TURRET AND THE BACK SADDLE A HEXAGONAL TURRET. JOHN LANG & SONS, JOHNSTONE, N.B

chine is used in gas engine work for drilling the two-bolt holes in the big ends of the connecting-rods. These are strapped to the front vertical face of the table, which is provided with tee slots, not shown in the illustration. If these rods are of any great length, a pit is necessary and the base plate has a gap at the front for this purpose. It is also used for boring the



UNIVERSAL FACING AND BORING MACHINE. GEORGE RICHARDS & CO., MANCHESTER. PEARNS PATENT



IMPROVED HIGH-SPEED PLANING MACHINE. BATEMAN'S MACHINE TOOL CO., LTD., LEEDS

gudgeon pin holes in cylinders, two at once being, of course, mounted on the table.

Bolt holes in cylinder ends and covers are very rapidly drilled, especially if they are mounted on a circular table which is drilled with a few rows of division holes. In this case the spindles work on opposite sides of the cylinder flange, and the holes in the covers may be relied on to coincide with those in the cylinder without having to drill both castings together.

Among recent horizontal facing and boring machines attention may be called to the universal machine built by Messrs. George Richards & Co., Ltd., of Broadheath, near Manchester. This machine is especially adapted for facing flanges on cylinders and similar work, and for finishing the brasses on connecting-rods, etc.

A special design of planing machine, intended to meet the requirements for high-speed steel in such work as the modern lathes have been designed for similar service, is found in the Bateman high-speed planer. Apart from the essential condition of great rigidity and massiveness, this planer is arranged to give high-cutting and quick-return speeds, without involving an expenditure of power.

The feed arrangement is of the friction type, and the amount of traverse can be altered, started or reversed while the planer is in motion. The drive has a very powerful purchase and is from both sides of the machine. A very important feature of the drive, the assistance of which makes possible the high speeds, is the arrangement of fly-wheel loose pulley. This arrangement is fitted on both sides of the machine. The one on the near side drives the cutting stroke and the one on the off side the return stroke.

The action of the clutch is as follows: The fly-wheel loose pulley is made to slide upon its shaft by means of a mechanism attached to the belt shifting device. This motion is so timed that when the belt is thrown on to the fast pulley the fly-wheel is attached to the fixed pulley by the cone faces of a clutch and also by the belt overlapping onto the fly-wheel. The conserved energy of the fly-wheel is thus transmitted into the fixed pulley at the moment when a large amount of power is required, owing to the sudden reversal of motion of the moving parts.

The assistance of the fly-wheel to the driving belt at this moment considerably reduces the loss of time during the acceleration of the table and makes the plane remarkably prompt.

The sudden reversal at high speeds of a loaded planer of these dimensions would undoubtedly cause breaking of the gears, were it not for the patented spring device on the table, previously referred to. In this the rack, instead of being rigidly fixed to the table, is free to slide longitudinally to a certain extent. The movement is controlled by four springs on each side of the sliding rack, the sudden strain due to the reversal of motion of all the moving parts being eased by the elastic action of these springs. The table, on returning, allows the compressed springs to return and assume their normal positions.

Current Topics

MORE than ten years ago there appeared in these pages an interesting communication from Professor John E. Sweet, describing the old works of Boulton & Watt, at Soho, now known as Handsworth, near Birmingham. This historic structure was pulled down in 1862, and Professor Sweet, then residing in England, made a sketch of what remained of the building, completing his drawing from the appearance of the portion then standing. We reproduce this drawing as it appeared in this magazine in the issue for March, 1897, in order to compare it with a most interesting contemporary engraving which has recently been brought to light.

THE OLD BOULTON & WATT WORKS AT SOHO, AS SKETCHED BY PROFESSOR SWEET AT THE TIME OF THEIR DEMOLITION IN 1862

As is well known, Mr. George Tangye, the owner of Heathfield Hall, the former residence of James Watt, has kept the room in which Watt did his private experimental work just as it was left at the death of the great inventor in 1819, and thus many engineers and admirers of the genius of Watt have been enabled to visit the relics there. The photograph gives an excellent idea of the room, showing especially portions of the carving and duplicating machine upon which Watt was engaged at the time of his death.

In 1903 Mr. Tangye found in this room a package bearing Watt's seals and, upon being opened, this was found to contain three impressions

WATT'S WORK ROOM AT HEATHFIELD HALL

of the certificate of membership in the insurance society belonging to the Soho manufactory, a fine old copperplate engraving, interesting not only for its associations and for the circumstances accompanying the discovery, but also because it bears, in the background, a view of the old works, as it actually appeared when it was in active service.

The reproduction of the certificate given here is one-half the linear dimensions of the original, and both in the style of the engraving and in the allegorical nature of the design it is a typical example of the work of the latter part of the eighteenth century, when it was doubtless made.

Professor Sweet has kindly permitted the reproduction of this memorial of Watt to be published in these pages as a confirmation of the accuracy of his sketch of forty-five years ago, and he has presented the original engraving to the American Society of Mechanical Engineers, where it will be treasured in the increasingly valuable collection of engineering relics in its possession.

IN a recent issue of CASSIER'S MAGAZINE mention was made of the removal of Messrs. Yarrow's shipbuilding yard from the Thames to the Clyde. Now Messrs. Humphrys & Tennant, one of the most famous engineering firms in the United Kingdom, have decided to close their extensive works at Deptford as soon as the orders now in hand are completed. The disappearance of this establishment marks practically the death knell to the engineering industry on the Thames banks, although the Thames Iron Works Company are still open to take orders. Time was when the riverside was alive with industrial activity, and thousands of skilled mechanics found regular employment. Those days are gone. For nearly a quarter of a century Messrs. Humphrys & Tennant have maintained a high position among engineering firms, and they have seldom lacked for orders to keep their shops running at full pressure. For more than twenty years they have cooperated with Sir W. G. Armstrong,

CERTIFICATE OF MEMBERSHIP IN THE INSURANCE SOCIETY OF SOHO MANUFACTORY OF BOULTON & WATT. RECENTLY DISCOVERED AMONG THE PAPERS LEFT BY WATT, AND PRESENTED TO THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS BY PROFESSOR JOHN E. SWEET. ONE-HALF SIZE OF THE ORIGINAL

Whitworth & Co., of Elswick-on-Tyne, and were responsible for the manufacture of the engines of the very efficient men-of-war which were launched from the Tyne for the Japanese fleet and took a conspicuous part in the late war. The Thames-side firm have also done a large amount of work for the British Admiralty and the mercantile marine. The reasons which have led to the abandonment of the enterprise which they have conducted with such conspicuous success are very much the same as those which have driven other firms from the Thames. In a letter to the press, Messrs. Humphrys & Tennant have explained the position very clearly, both as regards themselves and in respect of the general situation.

"It may, perhaps, be of some interest to point out the causes which have led us to come to this decision. (1) Wages are much higher than in any district of Great Britain. (2) Coal and material cost much more. (3) Rates are much higher. Perhaps the first and third of these are the more important from an engineer's point of view. Wages are higher now than they have ever been, and may be said to be abnormally high. Rates are also much higher. London municipal authorities fail to grasp the importance of doing what they can to assist industrial enterprises, which are a source of very great benefit to the district in which they are situated; they seem to be imbued with the idea that the more they can extract from the unfortunate employer the better. Take, for example, their action during the last quinquennial assessment when, making use of the vagueness of the wording of the law relating to the assessment of machinery, they very largely increased all assessments, and so placed an additional burden upon the users—in our case amounting to over 33 per cent. on one assessment and over 50 per cent. on another; there are, we believe, instances where the increases have been still greater."

IN view of the fact that all the torpedo craft which are now being built for the British fleet are to consume liquid fuel exclusively, the British authorities are busy making provision for the storage of fuel at Portsmouth and Devonport, and at the same time schemes have been drawn up for the efficient supply of oil to submarines. At Devonport a series of tanks is to be made, each capable of holding 5,000 tons, and six of these great receptacles will be constructed. The tanks will be at Turnchapel, which is an arm of Plymouth harbour. Jetties already exist, and these are to be greatly extended, so as to enable small craft to proceed alongside and be fed with liquid fuel or petrol by means of pipes. The advantages of this new departure in the fueling of small vessels are many, and not the least important one is that, instead of the crew having to exhaust themselves during war time in the very arduous work of placing coal on board their ships, in future the ships will be supplied practically without labour on their part. Consequently, when in time of war torpedo vessels put into one of the British naval bases for more fuel, they will be able to put to sea again after a relatively short withdrawal from operations with their personnel refreshed instead of being tired out with coaling operations, as is the case with craft as designed at present.

* * * *

WHATEVER may be the technical criticisms upon the *Dreadnought* design, there is no doubt that it marks a new departure in naval construction which will influence all the world's fleets in the immediate future. Every country which aspires to naval power is embarking upon the construction of huge vessels, embodying more or less completely the same principles as were adopted by the British Admiralty in the *Dreadnought*. It is true that the six French ships of the *Danton* class, which were authorized in 1906, did not fully embody the

one big gun principle, but the Conseil Superieur of the French Marine is already busy with a project for constructing six vessels resembling the British type of ship. Owing to the delays which have occurred in advancing the programme of 1906, the new group of veritable *Dreadnoughts* cannot make much progress beyond the paper stage for some years to come, and they will probably not be laid down before 1910. But the fact that the design of these ships is already the subject of discussion is an indication of the increasing rivalry in naval armament in Europe. The announcement of the intention entertained in France has come immediately after the publication of the details of a scheme for the further expansion of the German Navy. The German naval authorities have been greatly impressed with the *Dreadnought* design, and it has led them to form a poor opinion of many of the existing battleships of the German fleet, the largest of which has a development of only 13,000 tons. As a result of a vigorous agitation undertaken by the German Navy League, the Government feel confidence in approaching the Reichstag with a view to the elimination of three of these older battleships beyond the number specified in the Navy Act of 1906. If this proposal is adopted, by 1920 the German fleet will include twenty-one battleships more or less corresponding to the British *Dreadnought* and fifteen battleship-cruisers —Germany's reply to the British *Invincibles*. This amendment of the Naval Act will entail an additional outlay of nearly six millions sterling, which will be spread over a series of years. The mere fact that within a year or so of the passing of the Naval Act of 1906 the German authorities should feel no reticence in asking for increased provision for the navy is a sure indication of the enthusiasm which the naval movement has aroused throughout the German Empire. The activity in Germany will react on other European fleets, and France and Great Britain in particular will be put upon their mettle in order to maintain their present relative positions. The British authorities are averse to methodical shipbuilding programmes, such as are adopted in Germany periodically, and almost as quickly abandoned in favour of new projects. British naval policy is more elastic, and has the merit of simplicity. The root principle is that for every ship actually laid down by Germany two shall be commenced for the British Navy. The same principle applies to the French fleet, and by this method the British two-power standard is maintained. This standard does not necessarily involve the laying down, year by year, of twice as many ships as are commenced by Germany or France; in Germany the construction of a large armoured ship occupies three years and in France from five to six years, whereas in Great Britain the Royal Dockyards and private shipbuilding firms are pledged to the Admiralty to complete such vessels for sea within twenty-four months. Moreover, the shipbuilding resources of Great Britain are so huge that the British authorities are able to await full knowledge of foreign designs before committing themselves to the actual work of construction.

* * * *

We desire to correct a slight error which appeared in Mr. Bullock's article entitled "Who Built the First Steamboat," as regards the statement that the manuscripts of John Fitch were willed by him to the Franklin Institute, when, as a matter of fact, it was the Philadelphia Library, founded by Benjamin Franklin, which was made the depositary of the Fitch papers. The error is one which could hardly cause serious misapprehension, since the Franklin Institute was not founded until more than twenty-five years after the death of Fitch.

MINARD LEFEVER HOLMAN

President of the American Society of Mechanical Engineers

A BIOGRAPHICAL SKETCH

THE presidency of the American Society of Mechanical Engineers is one of the highest honours which the members of the profession can confer upon their distinguished companions. This year the choice has fallen upon a man highly esteemed, not only for the important works in which he has been engaged, but also for his eminent fitness for the position, involving, as it does, the administration of the affairs of an organization of increasing numbers and influence at a period when its usefulness is extending more widely than ever.

Minard Lefever Holman, who was unanimously elected president of the American Society of Mechanical Engineers at its recent annual meeting, was born in Maine, in 1852, his father being Colonel Holman, of the United States Supervising Architect's Department. His father removed to St. Louis in 1860, since which time the subject of our sketch has lived continuously in that city, so that he is eminently fitted to aid in the development of the interests of the society in the West.

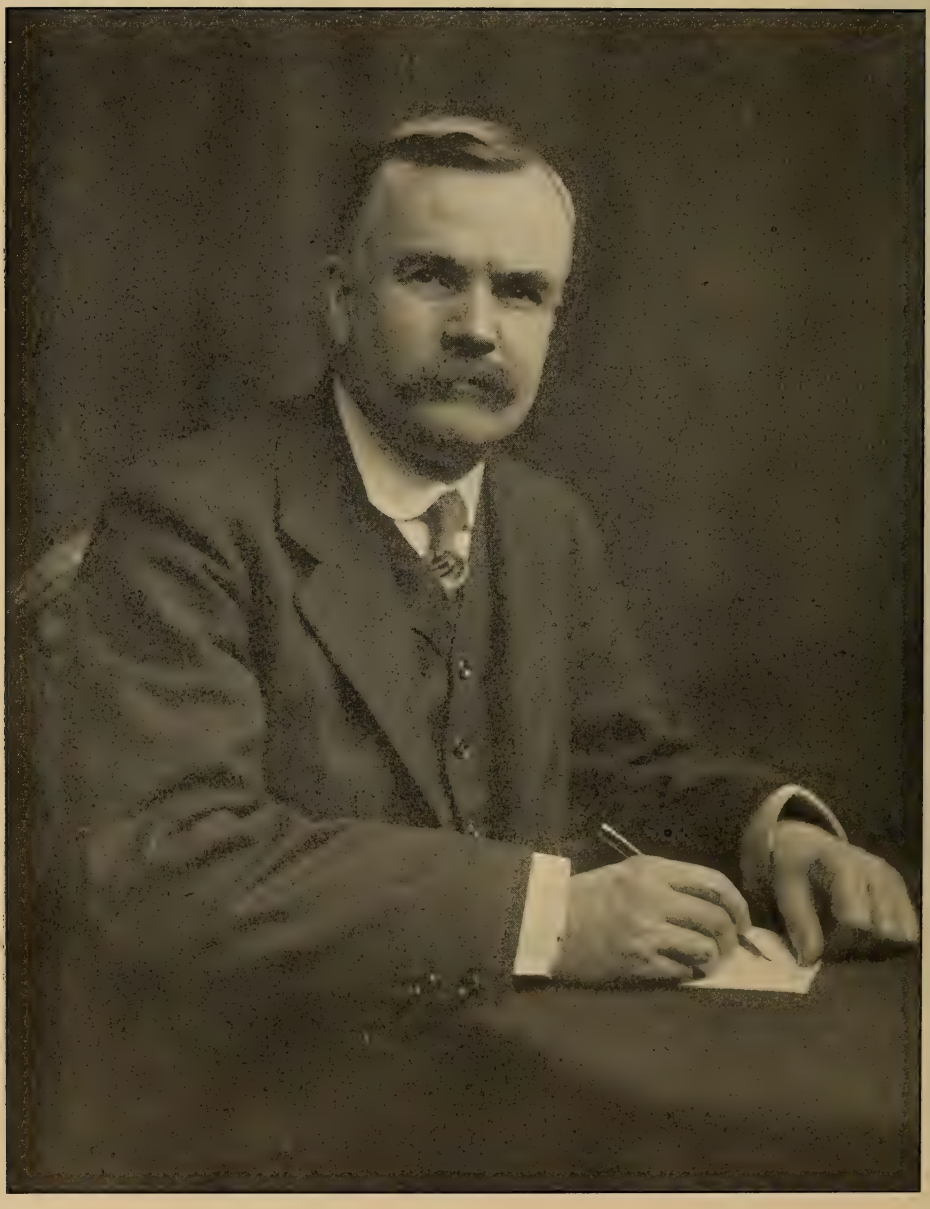
In 1874 Mr. Holman was graduated from the Washington University of St. Louis as a civil engineer, and he has since been the recipient of the honourary degree of Master of Arts from the same institution. His first practical work after his graduation was with the department of the United States Supervising Architect, but after several years he left this work to enter the St. Louis Water Department, then in charge of the late Thomas J. Whitman. Here he rose to the position of principal assistant engineer under Mr. Whitman, and in 1887 he was appointed Water Commissioner of the city of St. Louis, a position which he held for three terms, or twelve years in all. This period covered a most important epoch for the city, since in that time the St. Louis water-works were almost entirely reconstructed, this work including the extensive and successful experiments in the clarification of the Mississippi River water for use throughout the city.

After leaving the St. Louis Water Department Mr. Holman became general superintendent of the Missouri Edison Electric Company, which connection continued for four years, since when he has devoted his entire time to consulting work, having formed a partnership with Mr. John A. Laird, M. Am. Soc. M. E., under the firm name of Holman & Laird, of St. Louis.

Mr. Holman's extensive experience with water-works engineering has naturally led him to devote much of his attention to water-works and power plant engineering, and in these connections he has served on some important commissions, among which may be mentioned the commission intrusted with the design of a new water-works system for the city of Omaha.

At the present time Mr. Holman is serving on the special commission for the appraisal of the property of the Denver Water Company, his associates on this commission being Messrs. F. T. Stearns, John R. Freeman, C. L. Harrison and Allen Hazen.

In addition to his membership in the American Society of Mechanical Engineers, Mr. Holman is a member of the American Society of Civil Engineers, of the American Institute of Electrical Engineers and of the St. Louis Academy of Science, and is also an honourary member of the American Water-works Association.



T. & R. ANNAN & SONS, GLASGOW

JOHN HARVARD BILES

PROFESSOR OF NAVAL ARCHITECTURE IN THE UNIVERSITY OF GLASGOW

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CASSIER'S MAGAZINE

VOL. XXXIII FEBRUARY, 1908 No. 4

THE DEVELOPMENT OF SUPERHEATING APPARATUS FOR LOCOMOTIVES

By J. F. Gairns

AT a very early date in the history of the steam engine, indeed as soon as expansive working was introduced, it was realized that to counteract cylinder condensation, due to the deposition of suspended water vapour in the steam as the pressure falls during the expansion period, and even during the passage of the steam from the throttle to the cylinders and during its entrance thereinto, it was desirable to supply heat beyond the temperature corresponding to the steam pressure. To some extent the difficulty has been met by using cylinder jackets, and this method has been employed with some degree of success in the case of locomotive steam engines; but in stationary and marine practice very good results have been obtained by using superheated steam so that there is, as it were, a reservoir of heat contained in the steam itself for evaporating the water vapour that is carried over with the steam from the boiler, and for preventing the deposition of water as the pressure falls in working. For many years superheating has been very largely employed for various types of steam engines; but there are even greater possibilities attending the use of superheated steam for locomotives, so as to enable early cut-offs to be used without difficulty when an engine has a train well in hand, and for increasing the efficiency in other ways. Moreover, by superheating the volume of the steam is itself increased, so that the steam consumption for given work may be lessened as compared with the volume of steam generated. And as this may be effected with only slight decrease in boiler heating surface, with some constructions of apparatus with no reduction at all, the superheat being largely obtained by extracting further heat units from the furnace gases after they have passed through the boiler tubes, it will be seen that the possibilities of advantage are considerable.

In practice it has been shown beyond a doubt that the use of superheated steam is advantageous, not only for stationary and marine engines, but also for locomotive steam engines; but there have been important practical difficulties in the field of locomotive engineering which have prevented the extensive adoption of the use of superheated steam for locomotives until comparatively recently.

Some of the considerations which have influenced the design of superheating apparatus for locomotives, and difficulties which have had to be overcome before the superheater locomotive became a standard feature

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of locomotive engineering, may be expressed as follows:

(1) The apparatus has to be as simple as possible.

(2) It has to be of such construction that the boiler design does not require serious modification.

(3) The conditions of work vary between very wide extremes, far wider than ever occurs with other types of steam engines, but the apparatus must be efficient all the time and not liable to breakdown or undue wear and tear in consequence of such extreme variations.

(4) In order to apply superheating apparatus there must be no sacrifice of factors which affect the efficiency as a whole, or if any such sacrifice, as for example a reduction of heating surface, is entailed there must be more than adequate compensation in other ways.

(5) The apparatus must be easy of adaptation to locomotives not originally designed for it with a minimum of alteration; as well as for incorporation in designs for new engines.

(6) The apparatus must be adapted for easy removal if necessary and so constructed that ordinary operations, such as tube cleaning and tube changing, are not interfered with.

(7) The apparatus may often be subjected to a greater or lesser extent to considerable heat while steam is not being used and is not passing through the tubes.

(8) It must be easy to effect ordinary repairs to the superheater itself.

(9) The apparatus must be reasonably cheap to construct, apply and repair.

(10) The apparatus must not require special attention on the part of the engine and running shed staff.

In addition to these requirements incidental factors have shown themselves to be of importance.

(a) The superheated steam is deficient of some of the lubricating characteristics of ordinary saturated or wet steam, by reason of the absence of moisture.

(b) Special attention has therefore had to be paid, not only to the arrangements for lubrication by oil and other lubricants, but also to the choice and quality of such lubricants in order to withstand the high temperature of the superheated steam.

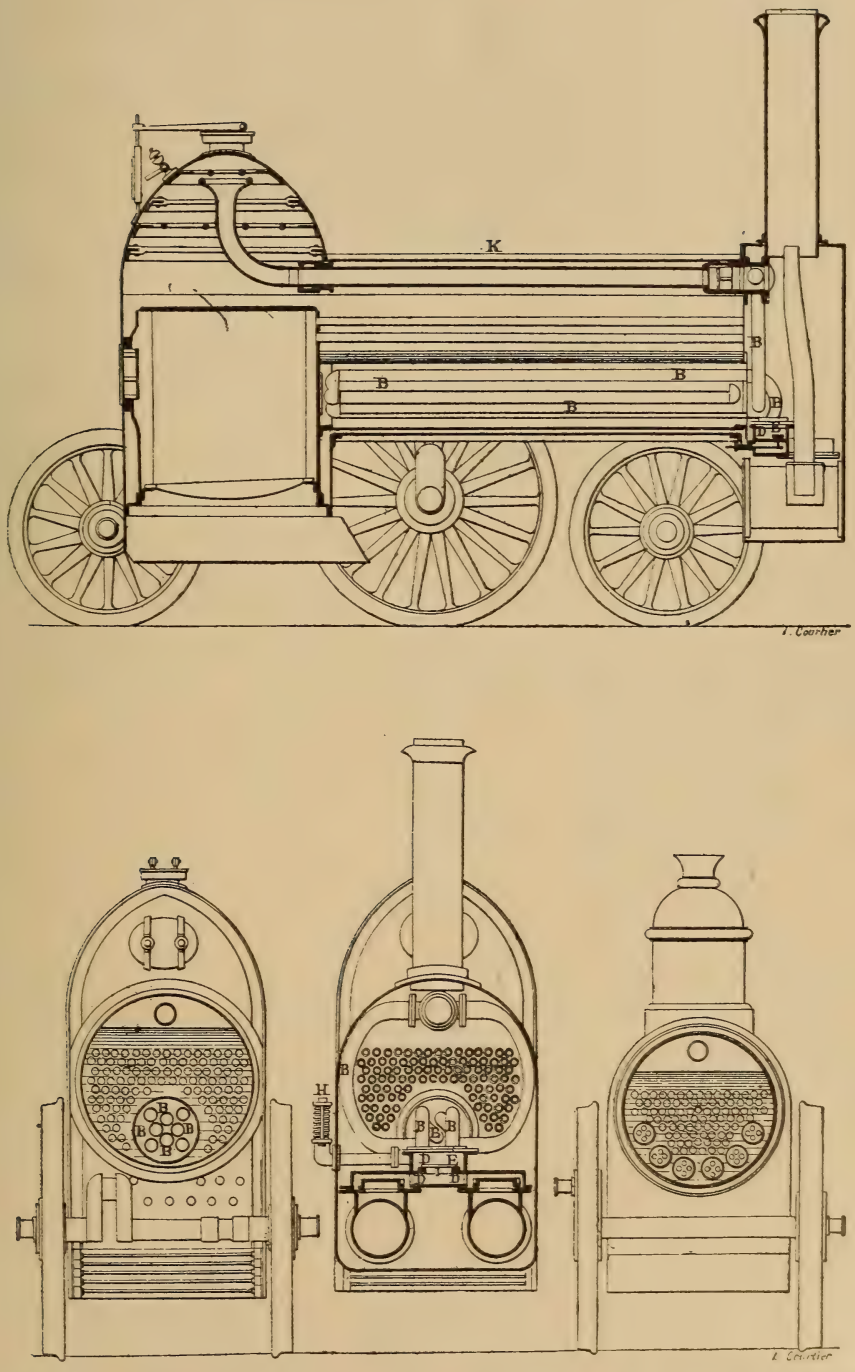
(c) Packings for stuffing boxes and pistons require special attention because of the heat and dryness of the superheated steam.

(d) It has been found desirable to employ piston valves instead of ordinary slide valves in most cases, and the design of such piston valves has proved a matter of importance.

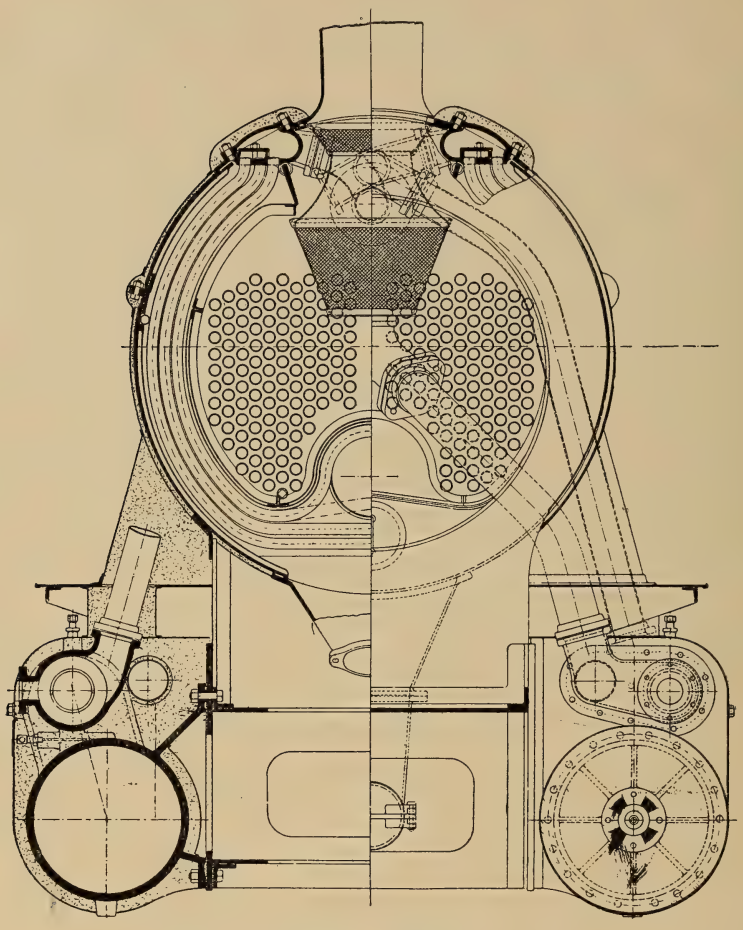
It will therefore be seen that the question of the advantage or not of the use of superheated steam for locomotives is far more complicated than it appears at first sight, and before a really successful apparatus was produced, all these factors had to be considered and provided for. In fact it is factors such as those mentioned that have prevented the introduction of superheating apparatus into practical locomotive engineering at an earlier date, for it has many times been suggested to use superheated steam for locomotives, and many designs have been prepared and patents taken out long before superheater locomotives were actually placed in service and successfully used.

How these various difficulties and controlling factors have been dealt with, so that, notwithstanding that the first successful superheater locomotive was introduced no earlier than 1898, there are to-day about 3,000 engines in use with various types of superheating apparatus on the world's railways, will be seen when the constructions now in use are considered. But before dealing with the various successful apparatuses in detail it will be advisable to briefly review the history of the superheater locomotive.

It is generally conceded, despite a few earlier references to the applicability of superheating apparatus not specially designed for locomotive purposes for such use, that the first



DESIGN FOR SUPERHEATER LOCOMOTIVE, PREPARED IN 1850 IN FRANCE, BY M. MONCHEUIL. CHRONIQUE DE LA SOCIETE DES INGENIEURS CIVILS DE FRANCE

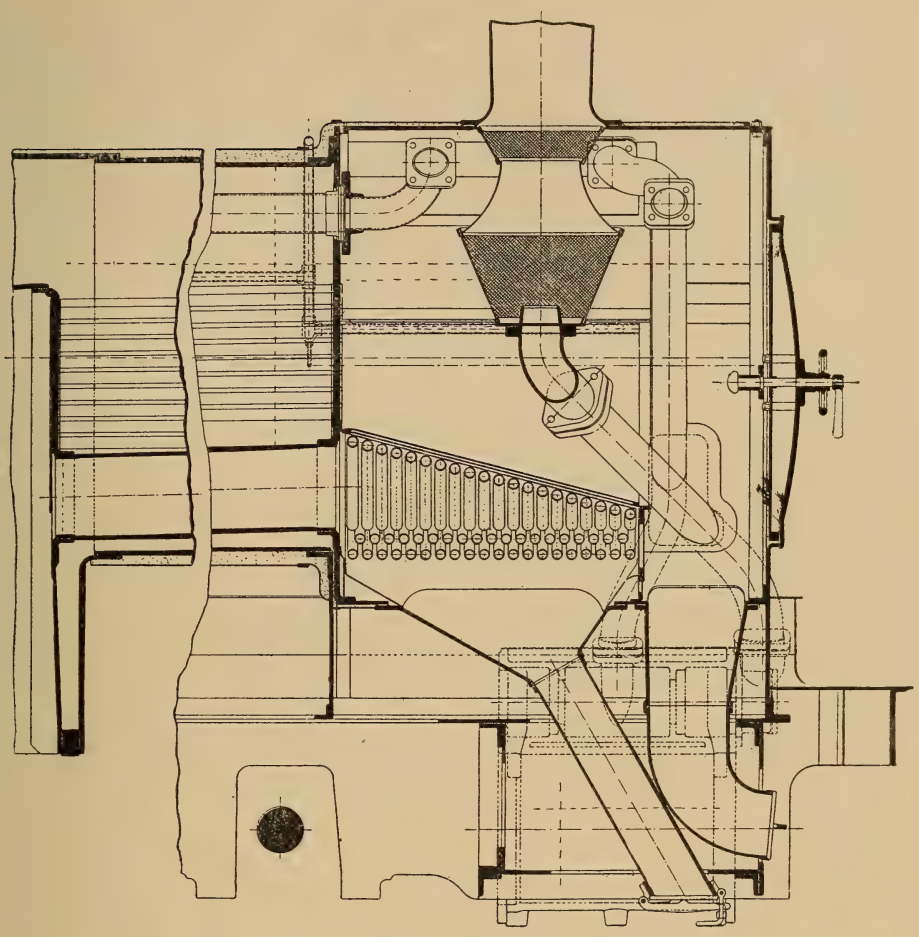


SCHMIDT SMOKE-BOX SUPERHEATER, FRONT VIEW

definite suggestion for a superheater locomotive is due to a French engineer, M. Moncheuil, in 1850, and we reproduce the drawings of this apparatus as contained in "La Chronique de la Société des Ingenieurs Civils de France" for December, 1906. The type of locomotive illustrated is one that was employed on the Montereau & Troyes Railway about 1847, but there appears to be no record that the apparatus was ever actually used, and it is doubtful whether it could have been of much advantage in view of the low steam pressures and the small expansion ratios then usual, and the comparatively small superheating surface provided.

The steam pipe is divided into two branches, curved round the side of the smoke-box, and then passes to a large fire-tube in the lower part of the boiler, where several return tube lengths cause the steam to pass to and fro several times while subjected to the furnace gases before it reaches the regulator, which consists of a slide valve located adjacent to the steam chests of the inside cylinder. As shown in another figure it was also proposed to employ a few large tubes in which four lengths of small steam piping were contained instead of the single large fire-tube shown in the other figures.

About 1870-'71 an experimental smoke-box superheater was tried in the United States on the Chicago,

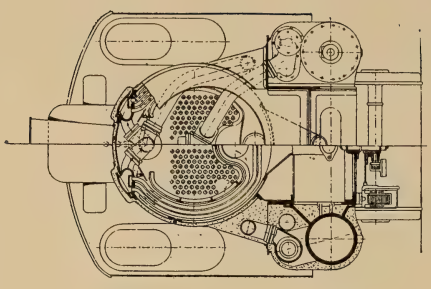


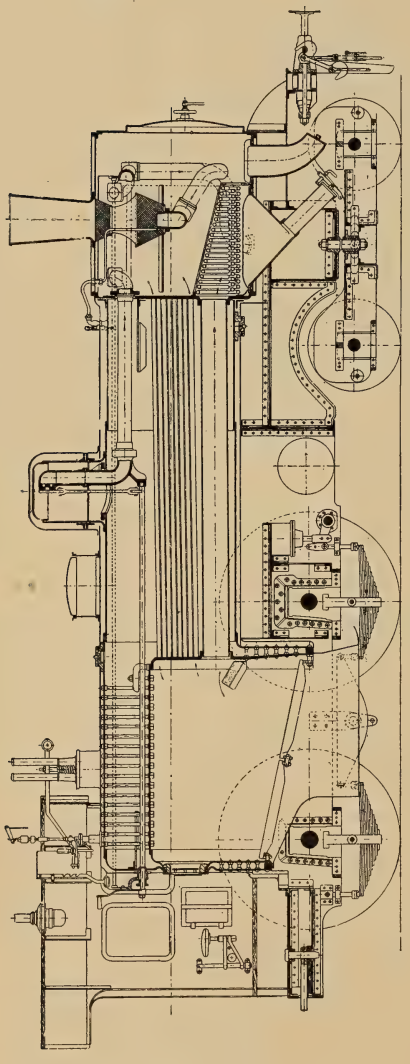
SCHMIDT SMOKE-BOX SUPERHEATER, SECTION

Burlington & Quincy Railroad, but without any notable result, so that nothing further was done until Herr Wilhelm Schmidt, a well-known German engineer, already responsible for a very successful type of superheating apparatus for stationary engines, was enabled (in 1898) to apply superheating apparatus designed by him to two express locomotives of the Prussian State Railways. With these original locomotives and two more express engines introduced in 1899 and two tank engines in 1900, a great deal of experimental work was done, and as the various difficulties manifested themselves, special designs of pistons, piston valves and stuffing boxes were evolved and tests made with various packings and lubricants. As a result of work with these engines the problem of employing superheated steam for locomotives was satisfactorily solved.

Actually, there are two forms of apparatus introduced by Herr Schmidt, both designed about the same time, though the smoke-box type of apparatus (as hereinafter described) was at first used, and adhered to by the Prussian State Railways for several years, though the smoke-tube type of apparatus has been principally employed elsewhere and is now in general favour in Germany also.

The fact that Herr Schmidt was able to develop the original experi-





GENERAL ARRANGEMENT OF SCHMIDT SMOKE-BOX SUPERHEATER

mental locomotives so as to produce a really satisfactory superheater locomotive, though there was never any necessity to appreciably modify the superheating apparatus itself, is undoubtedly due to the interest taken by chief officials of the Prussian State Railway administration and, among others, Herr Garbe, of the Berlin board of directors, must be specially mentioned.

In 1900 "smoke-box" locomotives were introduced for trial on the Moscow-Kazen Railway and the Canadian Pacific Railway, while in the following year many other railways introduced them. On the Belgian State Railways the first locomotive with the "smoke-tube" apparatus was introduced in 1901 by M. J. B. Flamme.

In 1903 two engines were fitted with the "smoke-tube" apparatus on the Canadian Pacific Railway by Mr. E. A. Williams, then superintendent of motive power.

About the same year the "Pielock" apparatus, which is of a totally different type from either of the Schmidt designs, was introduced by the Hanover Machine Company, and has been applied with considerable success to a number of locomotives in various parts of the world, though it has never been used to the extent that the Schmidt apparatus has.

In 1904 Mr. F. J. Cole, now chief engineer of the American Locomotive Company, but then superintendent of motive power of the New York Central & Hudson River Railroad, fitted his apparatus to an express engine of this line. In the same year the Canadian Pacific Railway introduced twenty locomotives with this type of apparatus and twenty-one with the Schmidt "smoke-tube" apparatus. Since that date a number of superheater locomotives have been introduced in the United States and Canada, particularly in the latter country. There are two forms of the Cole apparatus, but one has not proved very successful, we under-

stand, as it tends to become choked with ashes. There is also the Vaughan-Horsey apparatus, used largely in Canada, but these apparatuses are really constructional derivations of the Schmidt smoke-tube apparatus.

About 1904 a smoke-box type of apparatus was experimented with on the Lancashire & Yorkshire Railway, of England, but we understand that the results obtained were not sufficiently noteworthy for extended use.

About 1905 another construction of superheating apparatus was introduced by the John Cockerill Company in connection with a series of trials with various apparatus conducted on the Belgian State Railways, but this apparatus has not been extensively used so far.

Both the Schmidt and the Cole apparatus are being experimented with in Great Britain.

In addition to the apparatuses mentioned, several types of superheating apparatus have been introduced for superheating the steam in its passage between the high-pressure and the low-pressure cylinders of compound locomotives, and one or two of these will be described hereinafter.

In the early part of 1907 the well-known Baldwin Works introduced a type of smoke-box apparatus which has been applied to locomotives for several railways, though it is too soon for an extensive adoption to take place.

One or two other apparatus will be referred to later.

Before describing the various apparatus referred to in detail, the distribution of the various types of apparatus may be mentioned, though there are far more engines equipped with one or other of the Schmidt apparatuses than of all the others put together.

Dealing first with the Schmidt superheaters, the smoke-tube apparatus being understood except when the smoke-box apparatus is specially mentioned, in Germany the totals are 682 in service (July, 1907, as in other statistics given here) and 672 on order for the Prussian State Railways, of which all are non-compound, but 511 have the smoke-box apparatus; 16 (10 with smoke-box apparatus) in service and 38 on order, 40 being compound engines, on the Saxon State Railways; 22 in service (including two-rail motor cars with watertube boilers) and 29 on order (48 compound) on the Bavarian State Railways; 10 in service and 30 on order, all simple and fitted with special superheater, for the Prussian Army administration; 1 in service with the smoke-box apparatus (simple) and 10 (compound) with smoke-tube apparatus on order for the Alsace-Lorraine Railways; 7 on order for the Wurttemberg State Railways; 3 compound engines on order for the Baden State Railways; 1 compound and 1 simple engine in service on the Munich Suburban Railway; 1 compound and 1 simple engine in service on the Munich Suburban Railway, and 1 simple engine in service for the Voldagsen-Duingen Railway.

This makes a total of 1,523 engines (734 in service in July, 1907, and most of the others delivered soon after) for the whole of Germany, of which 521 have the smoke-box type of apparatus. The engines referred to comprise only 62 compound engines, all with four cylinders, the others being non-compound (6 with four cylinders in Saxony).

In Belgium 90 engines are in service and 180 others on order, all of which are non-compound (1 with four cylinders).

In Russia 73 are in service and 49 on order, including 19 with the smoke-box apparatus. All of these are simple except 30 Mallet articulated engines for the Moscow-Kazan Railway.

In Austria-Hungary 39 are in service and 29 on order, all non-compound.

In Sweden 24 are in service and 49 are on order, all non-compound.

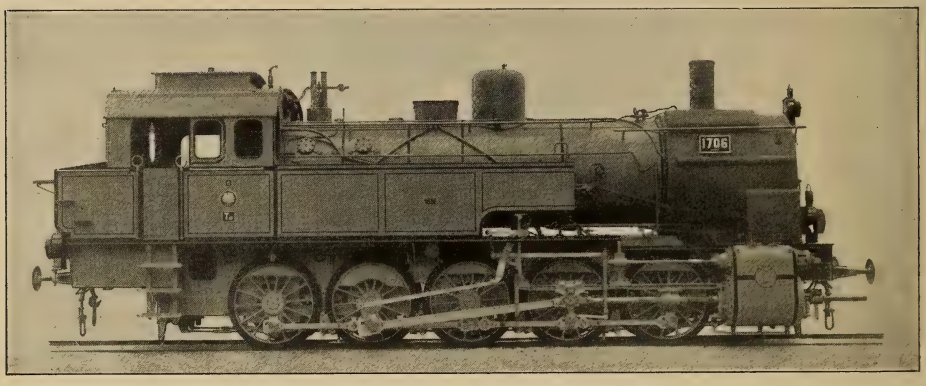
In Switzerland 20 engines are in

service (2 compounds included) and 32 on order.

In France and Colonies 5 are in service and 45 on order (1 compound for the P. L. M. Railway).

In North America 41 are in use (33 on the C. P. R. R.), of which 3 only (including one of the huge Mallet articulated engines of the G. N. R. R., United States of America) are compounds, the other two being on the C. P. R. R. The first of the C. P. R. R. engines has the smoke-box apparatus. Two engines are on order for a South American Railway.

In Italy 1 engine is in service and 28 on order.



TEN-COUPLED TANK ENGINE FOR THE PRUSSIAN STATE RAILWAYS, FITTED WITH SCHMIDT SUPERHEATER. BERLIN MACHINE WORKS, BERLIN

In Holland and the Dutch Colonies 3 are in service and 14 on order.

In Denmark 3 engines are on order.

In Spain 2 engines are in service.

In Greece 1 engine is on order.

In Great Britain there are to be 5 engines on the London, Brighton & South Coast Railway, 2 in service and 2 on order for the Lancashire & Yorkshire Railway, 1 on the Great Western Railway, 1 on the North British Railway and 2 on the Cape Government Railway (with the smoke-box apparatus).

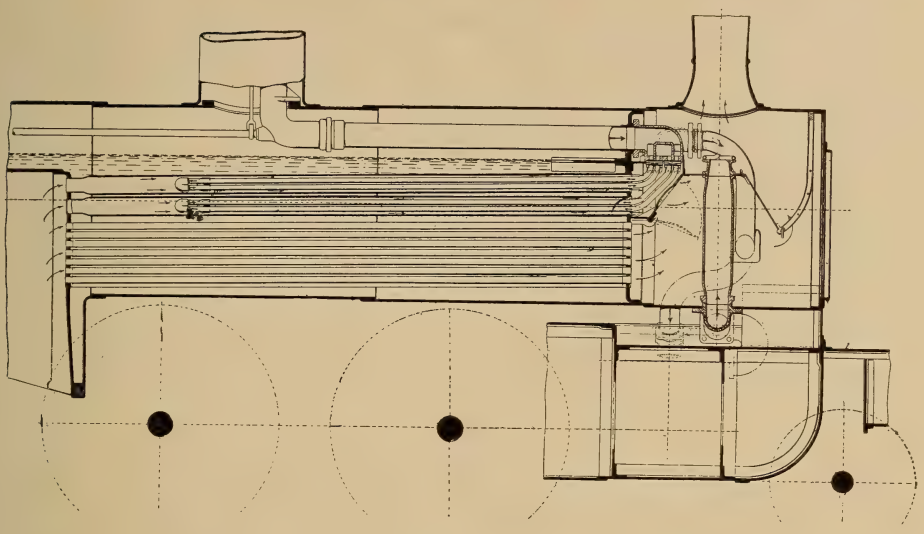
This makes a total of 1,026 engines in service and 1,240 on order (grand total, 2,266), of which 98 only are compound. By the middle of August the grand total was increased to 2,314 engines.

It may be mentioned that tests with compound engines have shown much less advantage by superheating as compared with non-compound working, for compounding has, to some extent, a similar result in effecting steam economy and reducing cylinder condensation, so that it is only to be expected that superheating apparatus should be used principally in connection with non-compound engines.

However, even in conjunction with compounding superheating has shown itself advantageous, and a total of 98 engines is fair evidence to this effect.

In North America there were, at the end of 1906, 197 engines in Canada (1 with Schmidt smoke-box apparatus, 32 with Schmidt smoke-tube apparatus, 21 with the Cole field tube apparatus, 55 with the Cole return bend apparatus and 88 with the Vaughan-Horsey return bend apparatus) and 15 engines in the United States (2 Schmidt, 1 Vaughan-Horsey and 12 with the Cole apparatus). An additional 175 engines with the Vaughan-Horsey apparatus for the Canadian Pacific Railway makes a total in service or on order of 372 locomotives, besides a few others on various American lines of which we have not complete details.

It is understood that an engine is being fitted with the Cole return-bend apparatus on the Great Western Railway, of England.



AN EARLY FORM OF SCHMIDT SMOKE-TUBE SUPERHEATER

The Pielock apparatus has not been very extensively used, principally because it is placed in the boiler itself, and is not readily accessible for repairs. According to the latest particulars available (not up to date), 13 engines with this apparatus are in use on the Prussian State Railways, 1 or 2 on the Baden State Railways, and about 30 in various other parts of the world.

The Baldwin superheater (entirely in the smoke-box) is of such recent date that only a few engines are yet in use.

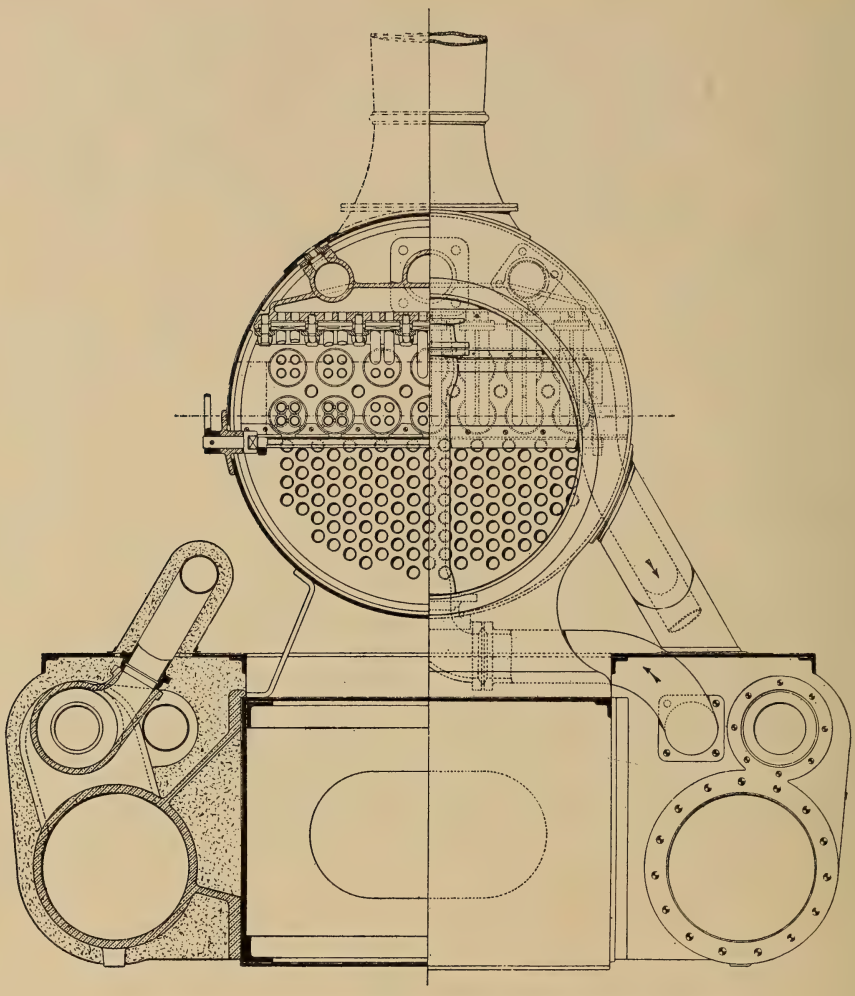
The Clench smoke-box apparatus (for moderate superheating only) is used to a slight extent in Germany and for a number of engines in Austria.

The various apparatus referred to will now be briefly described.

The Schmidt smoke-box apparatus was used in a remarkable ten-coupled tank engine, shown on the opposite page, and exhibited at Milan in 1907 by the builders, the Berlin Machine Works, this being one of the latest to be fitted with this type of apparatus. The engine, which is now employed on mountain work on the Prussian State Railway, is specially adapted for very steep gradients.

With the smoke-box apparatus, some of the gases of combustion flow through a single large flue tube in the lower part of the boiler barrel to the superheater apparatus in the smoke-box. The temperature of the gases entering the apparatus is comparatively high, and, therefore, a relatively small amount of heating surface suffices to highly superheat the steam before it reaches the valve-chests. Approximately 10 per cent. of the heat developed on the grate is employed in this way. The heating surface of the boiler is only slightly diminished, and the superheater actually increases the total heating surface.

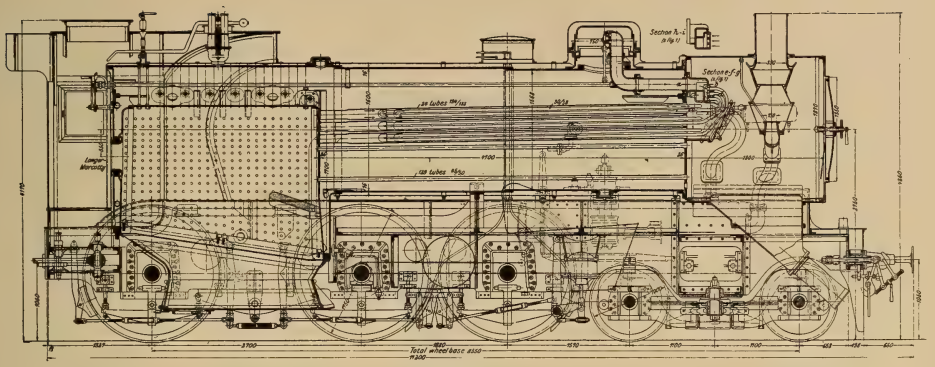
The superheater consists of a number of small tubes arranged in three concentric rows situated in the annular space of the extended smoke-box. The inner row is bent so as to constitute an arched continuation of the flame tube. This arch, which has a gradually decreasing radius towards the front of the smoke-box, thus forms a passage which conduces to a uniform distribution of the gases in the superheater. The superheater tubes are expanded into the walls of two cast-steel headers or steam chambers, which are fixed longitudinally inside the roof of the



CROSS-SECTION OF EARLY FORM OF SCHMIDT SMOKE-TUBE SUPERHEATER

smoke-box, one on each side of the chimney, and are attached to detachable steel casings, packed with asbestos. The space occupied by the superheater is separated from the remainder of the smoke-box by a wall of removable plates which extends almost up to the headers, and is shaped to the form of the superheater tubes, which, in turn, follow the contour of the smoke-box interiorly. This wall is protected from the hot gases by the tubes and from cinders by guard plates. The openings between the headers and the smoke-box walls are provided with dampers. For collecting cinders a hopper is provided, and soot can be removed from the superheater tubes while running by means of compressed air or steam controlled from the engine cab.

When the regulator is opened steam passes to the left-hand header and then through the inner row of tubes to the other header. Here the steam is directed by a baffle-plate into the central rings and thence returns to the left-hand header. By a baffle-plate the steam is then diverted to the outermost set of tubes and returns to the right-hand header, from which it passes to the cylinders. Therefore, the steam traverses the superheater



EXPRESS LOCOMOTIVE OF PRUSSIAN STATE RAILWAYS, WITH SCHMIDT SMOKE-TUBE SUPERHEATER

three times, and very efficient superheating results.

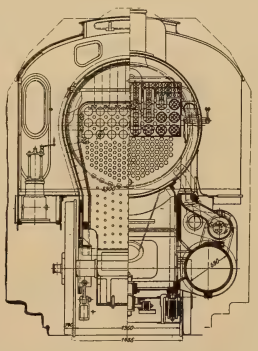
This type of apparatus has been very satisfactory, but the smoke-tube apparatus is now generally employed, as it is much simpler in construction and cheaper to maintain. In some cases the coils in the lower part of the apparatus are all the same diameter and the guard plate is horizontal.

The illustrations show an early constructional form of the Schmidt smoke-tube apparatus. Although there have been no serious modifications of this apparatus, there have been a few constructional changes in the few years that have elapsed since its first introduction, and these are illustrated in one of the latest engines to be fitted with it. The engine in question is a large 4-6-0 express locomotive for the Prussian State Railways recently constructed by the Berlin Machine Works, the drawings showing details of the superheater clearly.

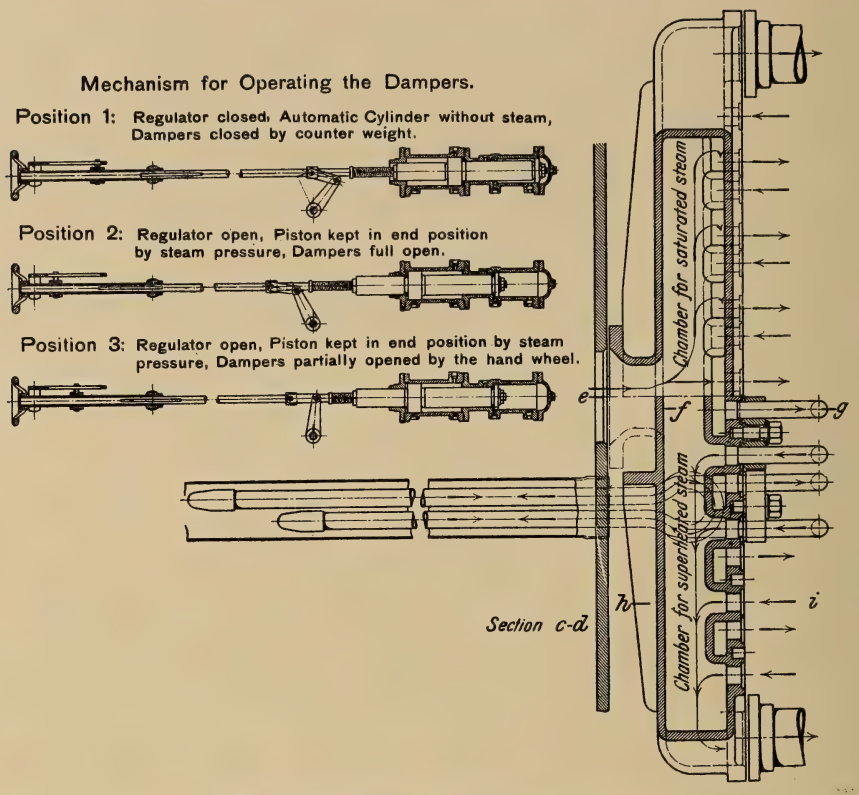
With the smoke-tube type of apparatus the upper part of the boiler is fitted with from two to four rows of large smoke-tubes, from 4 to $5\frac{1}{4}$ inches inside diameter, and inserted in each is a superheater element consisting of two sets of pipes bent in the form of a U and connected at the smoke-box end to a header, thus forming a continuous double-looped tube, through which the steam passes to and fro. In the original arrangement each element consisted of two separate single loops, but the double-looped construction in the superheater pipes as now employed has the advantage of increasing the velocity of the steam through the tubes, with the result that the temperature of the tubes is lowered and their life correspondingly increased.

The open ends of each element extend into the smoke-box, where they are bent slightly upwards and expanded into a common flange, which is secured to the face of the steam collector by a single central bolt.

Two slightly different methods are employed in arranging the pipe ends in the smoke-box. For instance, the pipes may be bent upwards only, in which case the flanges are horizontal, and are fastened by vertical bolts, the heads of which are movable in



CROSS SECTION OF LOCOMOTIVE WITH SCHMIDT SMOKE-TUBE SUPERHEATER


Mechanism for Operating the Dampers.
Position 1: Regulator closed, Automatic Cylinder without steam, Dampers closed by counter weight.
Position 2: Regulator open, Piston kept in end position by steam pressure, Dampers full open.
Position 3: Regulator open, Piston kept in end position by steam pressure, Dampers partially opened by the hand wheel.
Chamber for saturated steam
Chamber for superheated steam
e
f
g
h
i
Section c-d

REGULATORS FOR SCHMIDT SMOKE-TUBE SUPERHEATER

slots in the bottom of the collector casting. Or the ends of the pipes may be bent upwards and backwards, and connected to vertical flanges secured by horizontal studs to the steam collector. Both methods have been extensively used, the last named having been selected by the Prussian State Railways, while the former has found favour with the majority of other lines on account of its greater simplicity.

The construction of the steam collector and its connections to the steam pipe and valve chests are such that the steam from the steam pipes has to pass through all the superheater tubes simultaneously on its way from the boiler to the cylinders.

The flow of gases through the large tubes is controlled by dampers hinged or pivoted below the steam collector in the smoke-box. As long as the regulator is shut, these dampers are kept closed by a counterweight or a spring, but immediately steam is turned on they are opened simultaneously by means of a piston working in a small automatic steam cylinder. Thus, while getting up steam, or whenever the regulator is closed and the superheating pipes are not cooled by steam, no gases of combustion can pass through the large smoke-tubes and the superheating pipes are prevented from becoming unduly heated. Only when the regulator valve is opened can steam be admitted, and this is effected by a simple connection with the valve chest to the above-mentioned small steam cylinder for the purpose of opening the dampers. As the piston of this cylinder at the end of its stroke acts as a valve, which is kept closed by the steam pressure, leakages past the piston cannot cause a loss of steam, and the piston can,

therefore, be adjusted to work freely and reliably. In some cases the superheater dampers can be worked by hand from the foot-plate, independently of the automatic cylinders, so that any required degree of superheat can be attained. When the dampers are open they permit of a clear view through the superheater.

Soot and ashes can be removed from the large smoke-tubes, and from the superheater elements inside them, by means of either steam or compressed air, by means of a hose or nozzle. This operation is preferably carried out from the fire-box, but it can also be carried out from the smoke-box. As the cleaning of the large tubes with their contained elements can be effected much more rapidly by steam, or compressed air, than by brushes, the ordinary boiler tubes may be with advantage cleaned in the same manner.

The main feature of this type of apparatus lies in its thorough interchangeability and accessibility. Each individual superheater element can be removed and examined without disconnecting the whole arrangement by merely loosening the single nut securing it in position. At the same time, the smoke-tubes are rendered thoroughly accessible. This type of superheater can be adapted for use on either new or existing locomotives.

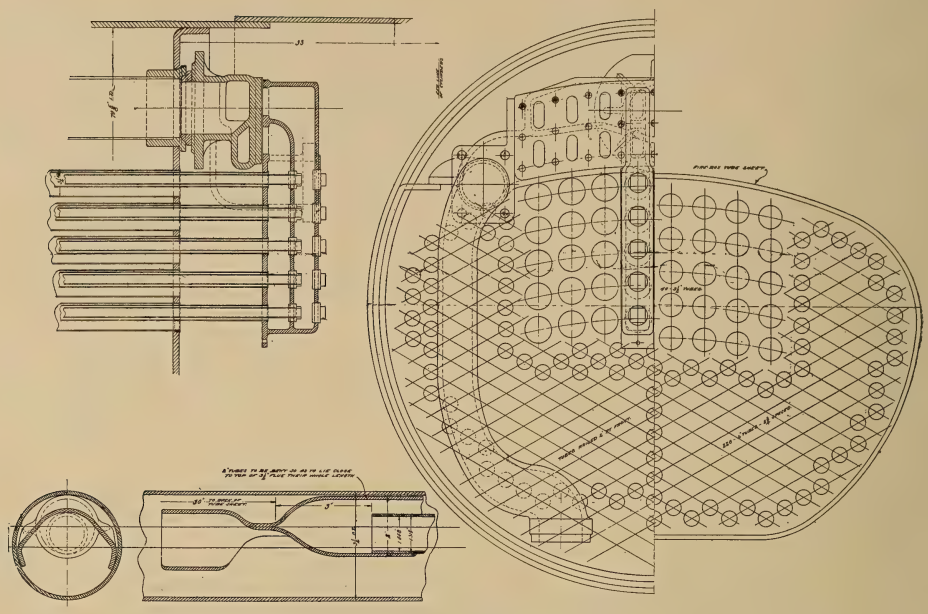
The Cole apparatus and the Vaughan-Horsey apparatus are really derived from the Schmidt smoke-tube apparatus, but they possess their own constructional feature.

ONE OF THE FIRST LOCOMOTIVES TO BE FITTED WITH THE SCHMIDT SUPERHEATER. BUILT BY A. BORSIG, TEGEL BEI BERLIN

The Cole field-tube type is illustrated, but the apparatus has not been largely employed, as it is difficult to keep the tubes clear of soot. The Cole return tube apparatus is in greater favour, while the Vaughan-Horsey apparatus is used on the Canadian Pacific Railway.

These apparatuses vary slightly in the arrangement of the superheater pipes in the smoke-tube, but differ largely in the form of the headers and the method by which the superheater pipes are attached to them.

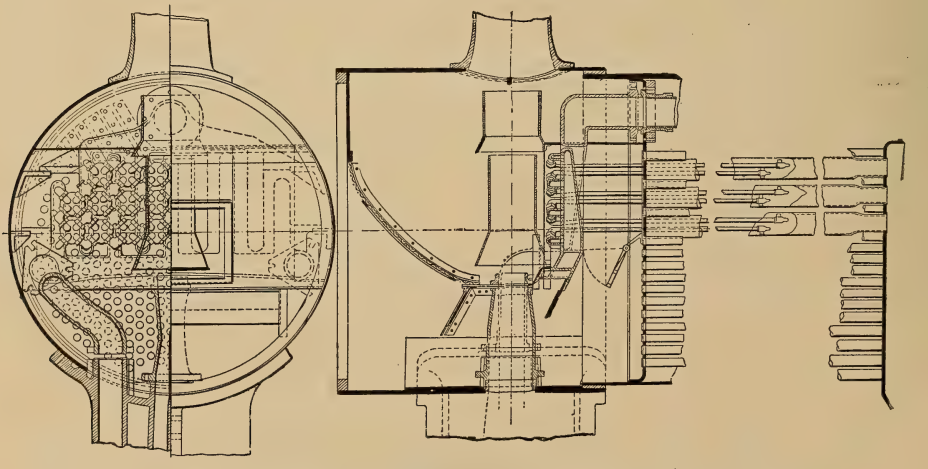
The Cole return bend type may be so arranged that the ends of each pair of superheater pipes enter the saturated and superheated steam head-



THE COLE FIELD-TUBE SUPERHEATER

ers, respectively, as shown, or the ends of each alternate pair may be joined together, thus forming a double loop in each smoke tube. In the Schmidt design each group of superheater pipes is united into one flange, which is detachable from the header. In the Cole design each vertical row of superheater pipes is connected into a sub-header, the sub-headers being detachable from the main header. In the Vaughan-Horsey type each pair of superheater pipes is detachable from fittings screwed into the main headers, which in this case are entirely separate and placed one above the other.

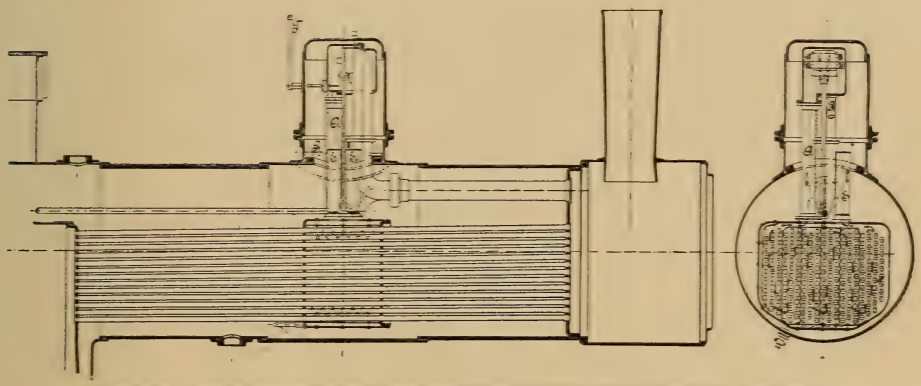
In all these arrangements the steam from the boiler is led by a dry pipe into the saturated steam header, thence through the loops of superheater pipes located in the smoke-



THE VAUGHAN-HORSEY SMOKE-TUBE SUPERHEATER
From a paper by Mr. H. H Vaughan before the American Society of Mechanical Engineers

tubes to the superheated steam headers, from which it is led by the steam pipes to the cylinders. The superheater headers are partitioned off from the body of the smoke-box, the partition extending to the tube plate and provided with an opening controlled by an automatic damper, by which the flow of gases from the firebox through the smoke-tubes is permitted while steam is flowing through the superheater pipes, but prevented when the throttle is shut and the flow of steam stopped.

The Pielock superheater exploited by the Hanover Machine Works differs



GENERAL ARRANGEMENT OF THE PIELOCK SUPERHEATER FOR LOCOMOTIVE BOILERS

essentially from the Schmidt apparatus, in that the superheater is fitted into the barrel of the boiler in such a manner that some of the heating surface of the boiler tubes is used, though it is located far enough from the firebox to prevent the tubes from becoming overheated.

The main part of the Pielock superheater is a box, into the end walls of which the boiler tubes are fitted. Ordinary tightness is sufficient, as the pressure inside and outside the superheater is the same.

This superheater is in some ways more economical than the smoke-box superheaters, because it can be put (within certain limits) where the heating gases are at the highest temperature, and the heat which is not used for superheating will be used for further heating of the water surrounding the tubes on its way to the smoke-box.

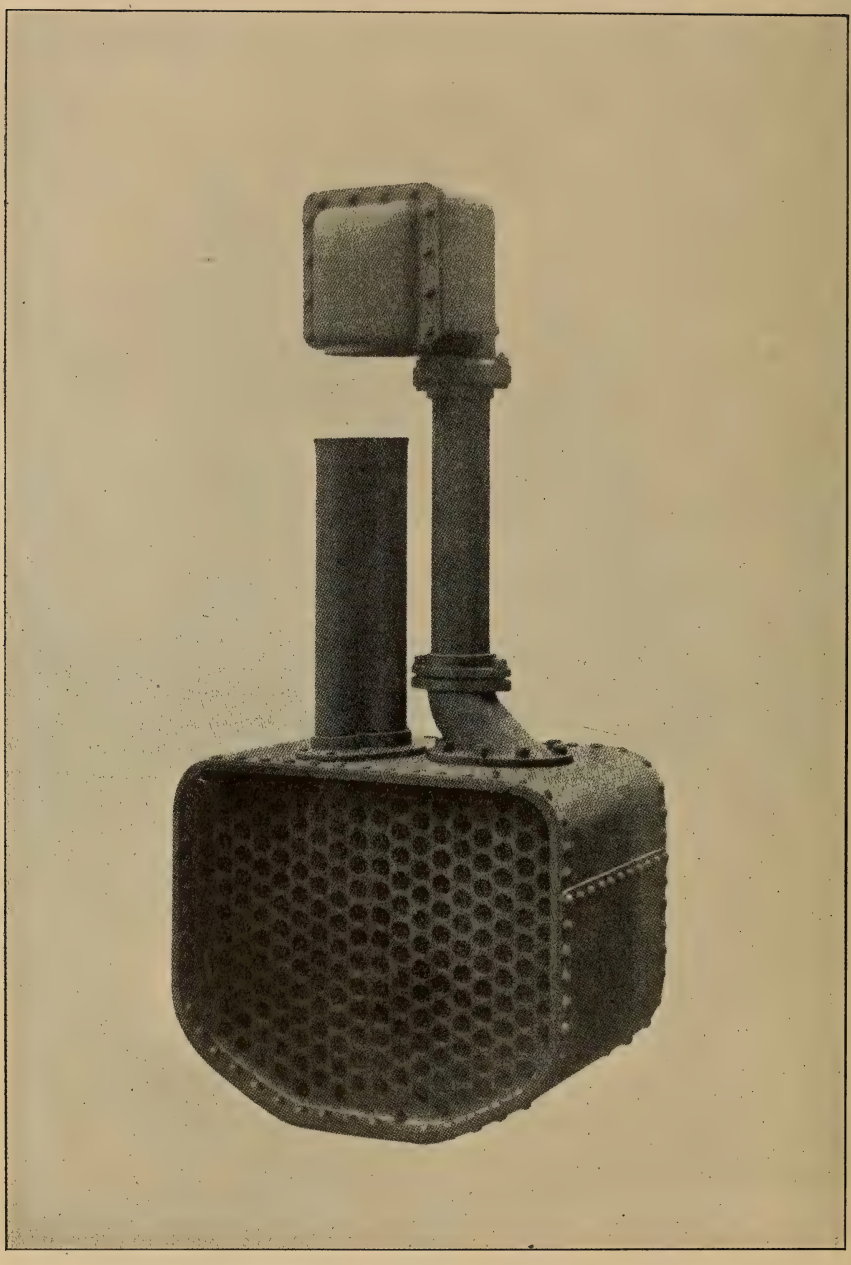
It does not necessitate any alteration to the locomotive to which it is applied.

The apparatus is safe for working, as the pressure inside and out is the same, and the strain on the boiler tubes remains the same, with or without the superheater. Overheating of the boiler tubes is impossible if the superheater is so far from the firebox that the temperature of the heating gases does not exceed 700 deg. to 800 deg. C. The steam, which passes round the tubes at high speed, cools them as effectually as the water which surrounds the tubes.

When the locomotive is at rest, no steam is passing through the superheater, and the temperature of the heating gases in the tubes is falling so quickly that it is impossible to overheat the tubes; the superheating of the steam is, however, still going on, and on starting the locomotive there is always superheated steam available.

The superheater requires very little attention, because its action is very even and no regulation is necessary. The work of the driver is not increased by the superheater.

It has been found in practice advisable to provide means for circulating a little steam in the apparatus when the engine is not working, and this is effected by a simple ar-

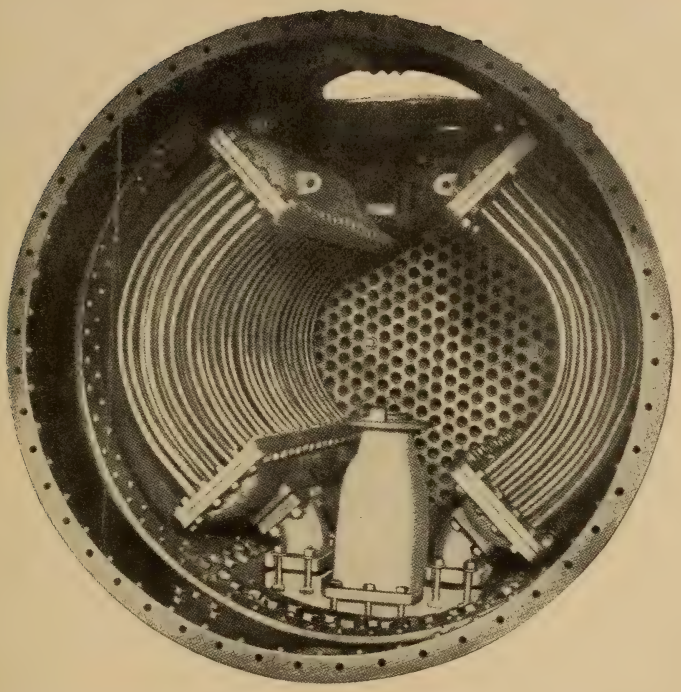


THE PIELOCK SUPERHEATER, SHOWING STEAM PIPES AND REGULATOR CHEST

rangement of pipes and controlling valves.

The Vauclain superheater, used by the Baldwin Works, of Philadelphia, is purely a smoke-box apparatus, and does not require any modification whatever in the boiler itself.

It consists of an upper and lower cast-steel drum for each cylinder, these drums being connected by curv-



THE VAUCLAIN SUPERHEATER, BUILT BY THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA

ing rows of tubes, which follow the contour of the smoke-box shell. The tubes are expanded into tube plates, which are bolted to the drums and are divided into separate groups, through which the steam is successively passed on its way to the cylinders. The heat of the waste gases is thus utilized as fully as possible for superheating purposes. The heated gases are compelled to circulate among the superheater tubes by means of suitably arranged deflecting plates.

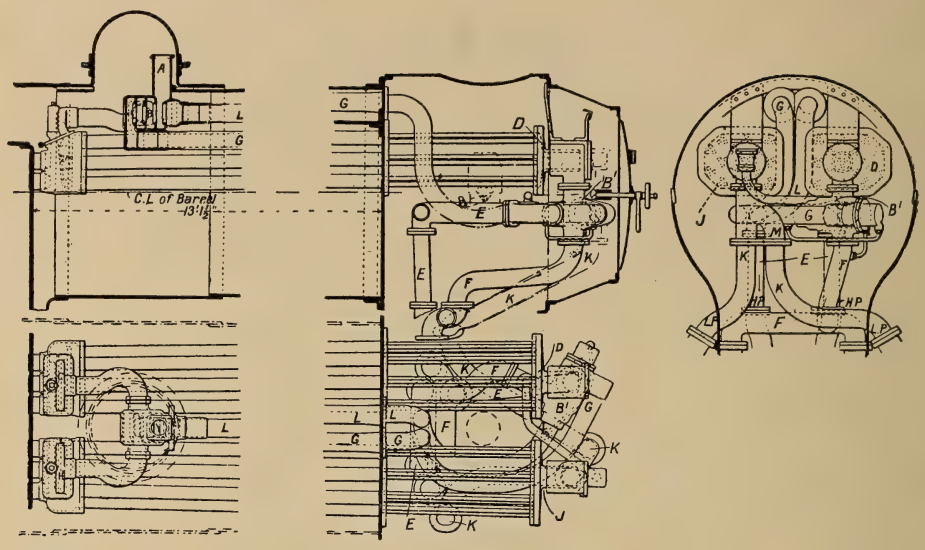
Besides apparatus of this class, several constructions of superheating apparatus, which effect only a small degree of superheating, have been used. A good example of this is shown in the illustration of a small "light" locomotive as used for hauling four or five small coaches on the sparsely populated sections of the Austrian State Railways. The general arrangement of the apparatus consists of a series of tubes in the smoke-box, through which steam passes from the high-pressure cylinder to the low-pressure cylinder. (Gölsdorf two-engine system.)

In 1905 another type of superheating apparatus was introduced by the John Cockerill Company and used for several engines of the Belgian State Railways, though it has never been very extensively employed. The apparatus is peculiar in that, in connection with four-cylinder compounding, it is adapted for superheating the steam between the high and low-pressure cylinders, as well as between the boiler and the high-pressure cylinders.

The apparatus is illustrated from the present writer's book on "Locomotive Compounding and Superheating.*

This apparatus was specially designed to enable trials to be made as to the advantages or otherwise of combining compounding and superheating. The superheater comprises

* Published by Messrs. Griffin & Co., Ltd., of Exeter street, Strand, London.



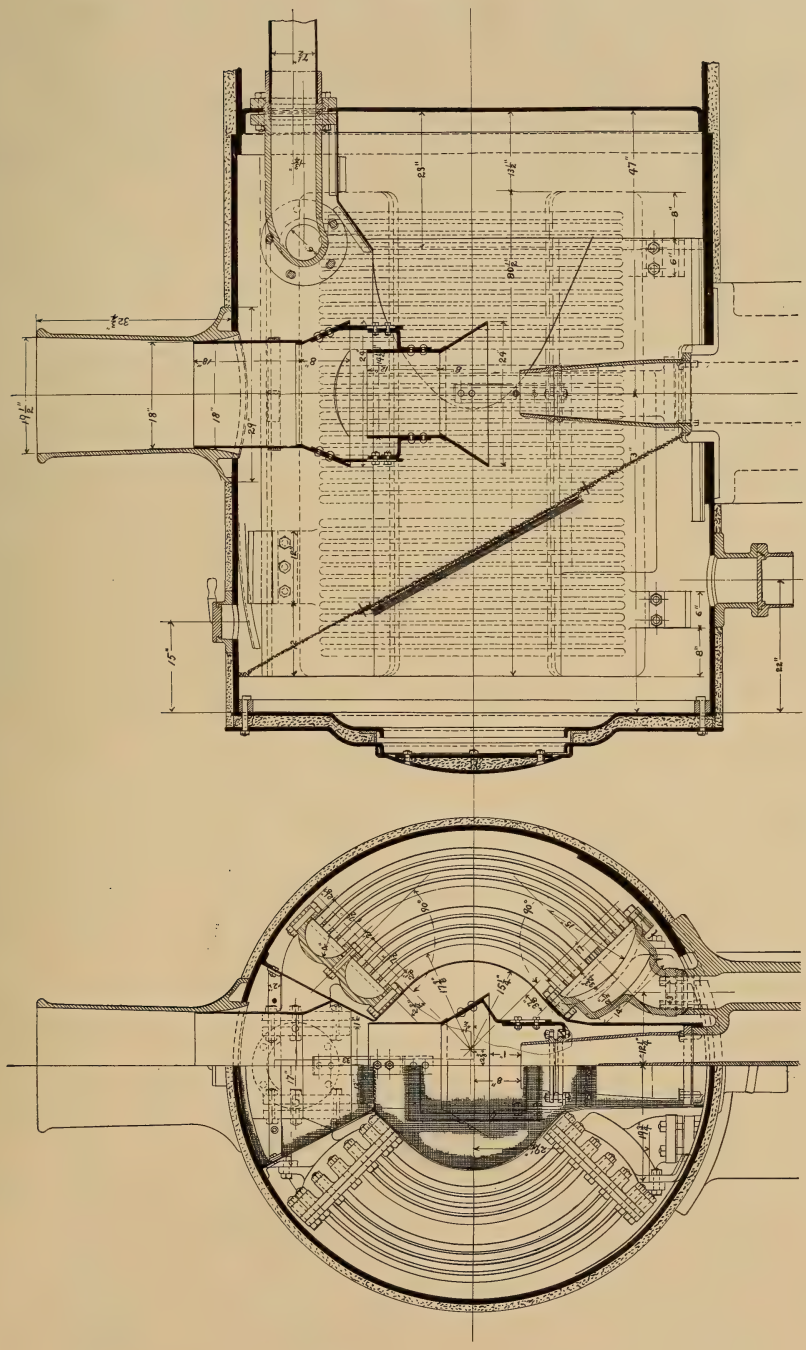
THE COCKERILL SUPERHEATER
From Locomotive Compounding and Superheating, by J. F. Gairns

two series of large flame tubes containing the circulating pipes for superheating the steam. At *B* there is a valve with three pistons, intended to divert the steam coming from the regulator towards the compartment *C*, or into the tube *L*, according as it is required to superheat the high-pressure steam, as well as the low-pressure steam, or the low-pressure steam only. The movements of the valve *B* are automatically repeated by an identically similar valve located within B^1.

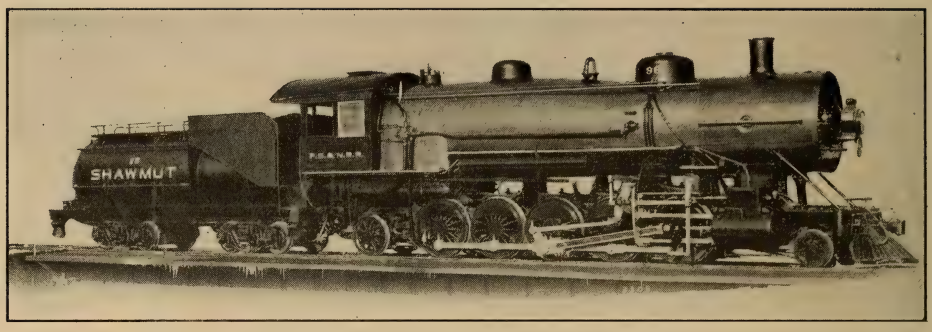
When superheating both for high pressure and low pressure, the steam, on leaving the regulator *A*, makes its way, after passing *B*, towards the compartment *C*; from there it traverses the left set of superheater tubes and enters the collector *D*, whence it goes to the high-pressure cylinders by passing through the valve B^1 and pipe *E*. The superheated steam, after doing work in the high-pressure cylinders, goes out by the exhaust pipe, and traverses the valve B^1 and the pipe *G*, in the interior of the barrel, to enable it to enter the compartment *H*. From there the steam goes into the superheating tubes, the right set, and reaches the low-pressure cylinders by the pipes *K*.

When superheating the low-pressure steam only, the valve *B* is moved, to divert the steam from the regulator into the pipe *L*; from there it goes to the high-pressure cylinders after having passed through the valve B^1 and the delivery pipes *E*. On leaving the high-pressure cylinders, the steam traverses the pipes *F* and the valve B^1 and enters into the collector *D*. From the front it passes back through the left set of superheater tubes and arrives at the compartment *C*. From this it passes through the valve *B* into the compartment *H*, and traverses the right group of superheater tubes, whence it goes into the collector *J*, and from there by the delivery pipes *K* into the low-pressure cylinders.

A design recently prepared by the officials of the New Zealand Government Railways, though, so far as the writer is aware, it has never been carried into practice, includes a type of superheating apparatus which provides for superheating to a medium extent between the boiler and the high-pressure cylinders and between the high-pressure cylinders and the



GENERAL ARRANGEMENT OF VAUCLAIN SUPERHEATER FOR LOCOMOTIVE ENGINES, BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA



THE FIRST LOCOMOTIVE FITTED WITH VAUCLAIN SUPERHEATER, 1907

low-pressure cylinders of a four-cylinder balanced compound engine, the steam passing through separate series of pipes located in the large smokebox.

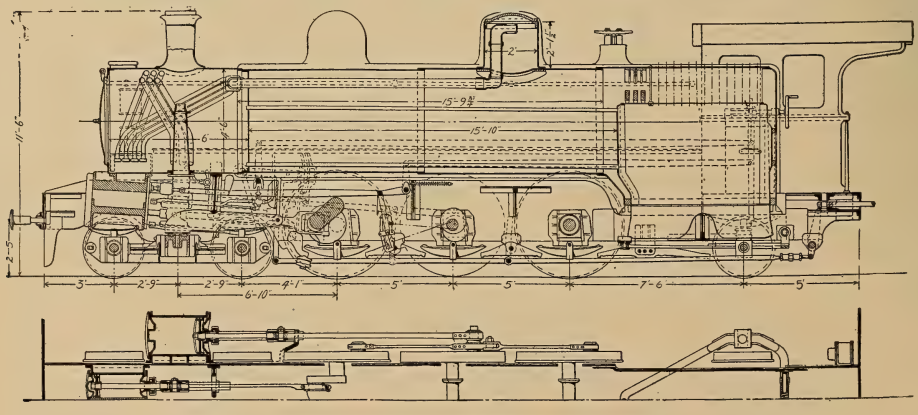
Considerable space could be devoted to a consideration of the various tests of superheating apparatus in Germany, Belgium, Canada, Austria, Sweden, France and the United States, but it is only possible on this occasion to briefly review the results.

With the Schmidt apparatus the following figures are claimed to represent a safe average of the economy effected:

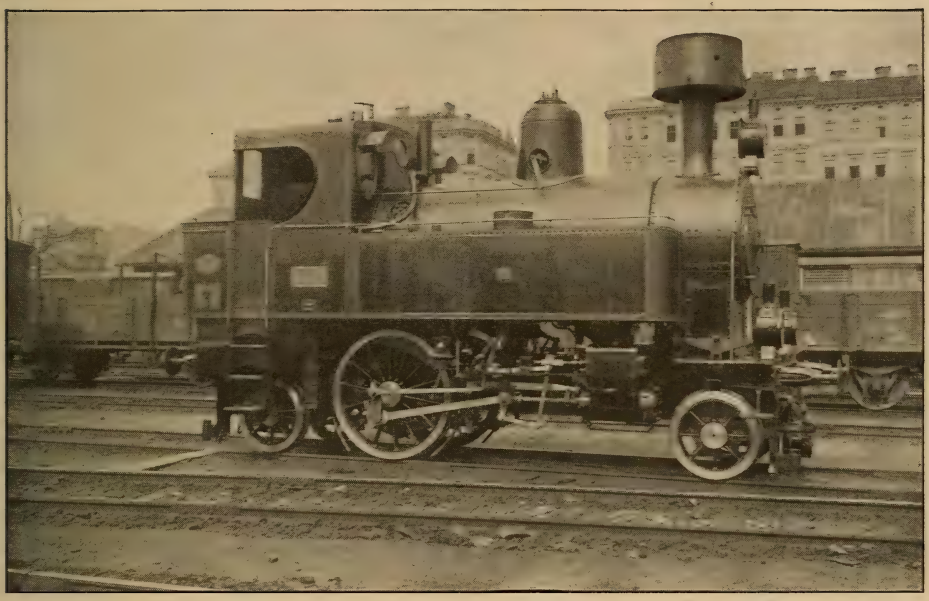
A simple engine using superheated steam shows an economy in coal of 20-25 per cent., as compared with a simple engine using saturated steam, and a simple engine using superheated steam shows an economy in coal of 5 to 15 per cent., as compared with a compound engine using saturated steam. With superheated steam there is also a considerable increase in haulage capacity, as the steam can be used more efficiently.

Finally, as to cost of repairs and maintenance, which must be debited against the gain by superheating, the following opinions of prominent engineers concerned will be of interest:

(1) Mr. H. H. Vaughan, superintendent of motive power, Canadian Pacific Railroad: "In general, it may be assumed that the maintenance of locomotives using superheated steam will not necessarily be greater than that of ordinary locomotives of similar size, as, although certain additional expenses are introduced, these are offset by economies in other directions, and the net result will not be very much different. If this position is correct, the advisability of superheating depends entirely on the relation between the initial additional



BALANCED COMPOUND LOCOMOTIVE WITH SUPERHEATER. NEW ZEALAND STATE RAILWAYS

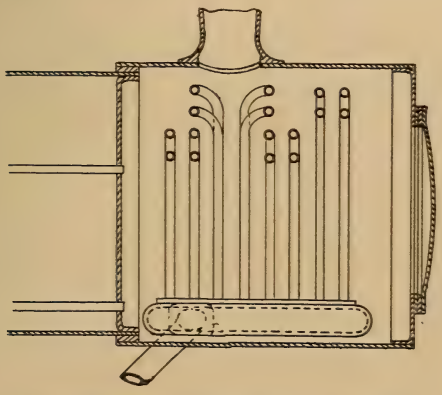


LIGHT LOCOMOTIVE, AUSTRIAN STATE RAILWAYS, FITTED WITH SMOKE-BOX SUPERHEATER

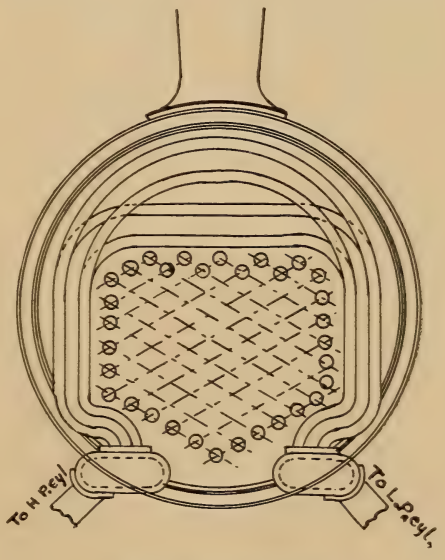
cost and the saving obtained; and as, at present, the cost of applying a superheater is about $1,000 per engine, and the tendency will be rather to reduce this amount than increase it, it is evidently a very good investment."

Mr. Vaughan estimated also that the extra cost of a superheater steam locomotive would be recouped within two years.

(2) Mr. Garbe, of the Prussian State Railways: "It can be positively asserted that modern superheated steam locomotives do not involve any greater cost of maintenance than ordinary saturated steam simple engines, and that they are much cheaper to maintain than four-cylinder compound locomotives. This is



ARRANGEMENT OF TUBES IN THE CLENCH SUPERHEATER



THE CLENCH SUPERHEATER
Front view, showing tubes in smoke-box

proved, for instance, by the results lately obtained with the six-coupled (2-6-0) superheated steam tank locomotives in the Berlin suburban service. Each of these engines, during one and one-half years' service, covered from 60,000 to 73,000 miles before it had to undergo the first general shop repairs, and each showed only the usual wear in the running parts. No repairs to the superheaters, cylinders and kindred parts were, however, needed."

(3) Mr. J. B. Flamme, general inspector of the Belgian State Railways: "As regards maintenance, the superheated steam locomotive, type 35, has not required special attention during its one and one-half years' service. The early favourable results have led the Belgian State Railways to venture on the application of superheated steam to locomotives on a larger scale."

(4) Mr. O. Nyströmer, superintendent of motive power, Bergslagernas Railway, Sweden: "I can inform you that, up till now, we have not had any direct cost of maintenance for the superheating arrangement of our locomotive No. 52 (in service since June, 1905). The total cost of repairs for this engine, up to the beginning of this year, amounted to 871 kronen (about £48), but no part of this was attributable to superheating. My experience is, as yet, too short, but if I may express any opinion, it is, that the cost of maintenance for the superheated steam locomotive, fitted with the Schmidt smoke-tube superheater, is less than that of an ordinary saturated steam engine of the same type."

In conclusion, the writer must acknowledge the courtesy of Herr Wilhelm Schmidt, Mr. H. H. Vaughan, Herr K. von Gölsdorf, the Hanover Machine Works, the Berlin Machine Works, the American Locomotive Company, the Baldwin Works and others who have provided illustrations and particulars of the variout types of superheating apparatus described herein, their developments and the results obtained.

ADDENDUM

Since the above was prepared the writer has received a copy of "Die Dampflocomotiven der Gegenwart" (J. Springer, Berlin, 500 4to pages, 388 illustrations, 20 folding plates), by Herr Robert Garbe, chief engineer of the Prussian State Railway administration at Berlin, and for all who are sufficiently interested in locomotive superheating to pursue its study, this work can be cordially recommended, for it contains practically all that can be said on the subject at present, and is written by the gentleman who, in conjunction with Herr Wilhelm Schmidt, has probably had more to do with the development and experience with superheater locomotives than any one else. The smaller first part deals with some of the more noteworthy features of recent locomotive practice, American practice receiving considerable attention; but the most important section, and which constitutes the *raison d'etre* of the work, is the second part, which is devoted to a history of superheating apparatus for locomotives, descriptions of engines fitted therewith, construction of superheating apparatus (all designs in use), detailed constructive features and appliances in connection therewith, design and practice as regards slide and piston valves, packings, etc., and a long series of records of tests carried out upon the Prussian State Railways. The work is a voluminous production, and is well produced and profusely illustrated, usually with drawings.

THE EVOLUTION OF THE PETROL CARBURETER

By J. Wright

IT is an indisputable fact that the carbureter of a modern petrol-engined motor car, or cycle, though seldom so regarded by the user, is one of the most important details in its somewhat complex organization, in that, upon the efficiency with which it performs its functions, viz., that of carbureting the air supply to the engine, depends the brake-horse-power developed by the latter at any given time, to say nothing of the influence which it otherwise exerts upon smoothness and silence of running, wear and tear of the moving parts, etc.

It must be remembered that the engine of a motor vehicle works under conditions entirely different from those which obtain in the case of a stationary internal-combustion engine. The load upon an automobile engine is constantly varying within very wide limits, with the nature of the road, gradients, speed, weight, gear, etc., and is consequently of a nature which cannot be satisfactorily dealt with by any form of automatic governor such as is applicable to the stationary engine. When to these facts is added the testimony of the chemist, to the effect that the vapour of the hydro-carbon, popularly known as petrol, is capable, when mixed with varying quantities of air, of forming an explosive mixture, whose effectiveness is subject to such variables as atmospheric pressure and humidity, to say nothing of the percentage volume of petrol vapour present, it is obvious that the design of a perfect carbureter, or device for automatically supplying the engine at all times and under all atmospheric conditions, with a mixture of petrol vapour and air of maximum explosiveness, is far removed from the simple problem it would, at first sight, appear.

To describe, in anything like detail, the evolution of the petrol carbureter, from the early surface type to the modern aspiration pattern, would fill a volume of no inconsiderable dimensions, and the writer purposes, therefore, in the present article to deal with a few of the more modern types, describing one or two of the best known designs without prejudice to the remainder, in order to illustrate the general trend of the designer towards automatic action.

For the benefit of the uninitiated, it may be mentioned that the aspiration or, as it is more popularly known, "spray" carbureter, consists in its simplest form of a reservoir *A*, Fig. 1, supplied with liquid petrol from the main fuel tank by way of the feed pipe *B*. The supply is regularly maintained at a constant level in this reservoir by the automatic action of a hollow metal float *C*, actuating a needle-valve *D*, through the medium of the small bell crank levers *a a*, the principle of control being as follows: When empty, the float *C*, pressing upon the levers *a a*, raises the needle *D*, allowing petrol to flow in from the fuel tank; when the petrol in *A* reaches a certain predetermined level, the buoyancy of the float causes it to rise, allowing the needle *D* to descend and close the inlet. This action is entirely automatic, and ensures a constant "head" of petrol, whatever the demand made upon it by the engine in response to a varying load. The jet, or spraying nozzle *E*, is in direct communication

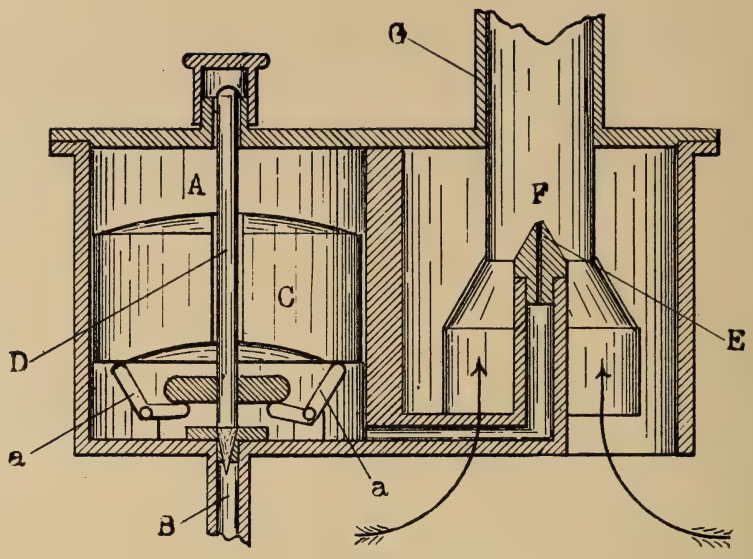


FIG. 1.—THE SPRAY CARBURETER

with this reservoir or float chamber, and is surrounded by a funnel or choke tube *F*, through which the main air supply of the engine is drawn by the action of the piston descending on the induction stroke. The reader will now be able to follow the general cycle of operations which take place while the engine is running. The suction exerted by the descending piston upon the inlet pipe *G* creates a partial vacuum therein, with the result that the normal atmospheric pressure, acting upon the surface of the petrol in the reservoir *A* forces it up through the jet in a fine spray, thereby assisting vaporization. In order to facilitate the mixing of the petrol vapour with the main body of air passing through the choke tube *F*, the latter is contracted as shown, where it surrounds the jet, thus increasing the velocity of the moving air at this point.

Assuming a correct proportioning of the effective areas of the spraying nozzle *E* and choke tube *F*, we have here, given an unvarying load and engine speed, all the conditions necessary for good carburation; but it must be remembered that both load and engine speed in a motor vehicle vary between very wide limits, and it becomes obvious that some means must be provided for dealing with these variations as they occur, and still maintaining a correct mixture in the engine induction pipe. To cope with varying loads, the somewhat reprehensible practice of charge volume throttling is adopted on most cars; in other words, the volume of gas admitted to the engine cylinder is controlled by an adjustable throttle valve located between the carbureter and the cylinder inlet, this throttle valve being opened more or less, according to whether the work which the engine is being called upon to perform is heavy or light. This system of charge volume throttling, although economical of fuel, possesses one serious disadvantage, viz., that of rarifying the charge taken into the cylinder. Now to enable a four-cycle engine to run to the best advantage, it is necessary to fill the cylinder with gas at every induction stroke. If the throttle valve be closed, or nearly so, it is obvious that the gas supply to the cylinder is restricted, the result being that the charge, instead of entering at approximately atmospheric pressure and being subsequently compressed, enters the cylinder in a rarified state, so that, not only is its ex-

plosive efficiency reduced, but the great advantage of compression is lost, inasmuch as the ascending piston, in the case of an attenuated charge, merely restores it to its normal density, or very little in excess

Now let us consider the effect of the throttle upon the action of the carbureter. With a closed, or nearly closed, throttle, the air surrounding the jet *E* will be very nearly at normal pressure, and consequently the quantity of petrol passing the jet will be minimum, or, in the event of an absolutely closed throttle, nil. As the throttle valve is opened, the pressure around the jet decreases, with a corresponding increase in the quantity of petrol passing. Thus far the action is as it should be, and is conducive to regular carburation. Let us now, however, consider the effect of varying engine speed upon the behaviour of the carbureter. Here we have an anomalous set of conditions to meet, inasmuch as the engine of a motor vehicle, to properly fulfill its duties, is called upon to deal with heavy loads or light loads, at both high and low speeds, respectively; in other words, the engine is required to run satisfactorily under all possible combinations of speed and throttle opening.

At high engine speeds the carbureter conditions are synonymous with those which obtain when the throttle is open; the higher the speed, the lower the pressure around the jet, and consequently the greater the volume of petrol passing, and *vice versa*. When, however, the two influences are brought to bear conjointly upon the carbureter, we have a set of conditions which the simple carbureter construction indicated in Fig. 1 is unable to cope with satisfactorily. For instance, given a high engine speed and a nearly closed throttle, the effect of the latter is to counterbalance the condition created by the former, viz., that of lowering the pressure around the jet, whilst it is obvious at the same time that the higher speed calls for a more rapid passage of petrol through the spraying nozzle. Similarly, a low engine speed influences the action of the carbureter in an opposite sense to the open throttle, with which it is frequently associated.

Summarizing these widely divergent conditions, the reader will readily grasp the fact that a fixed area of spraying jet, in combination with an equally fixed air intake, however satisfactory it may prove for one given engine speed and load, cannot possibly adapt itself to the varying conditions under which the automobile engine performs its duties. The air passing through the choke tube *F* (Fig. 1), if correctly carbureted for one set of conditions, will be over-rich in petrol for another, and of poor quality for a third.

This brings us to a point at which we have to consider how these varying conditions may be met and compensated automatically, the primary object being to provide the engine, under all possible conditions of load and speed, with a constant explosive mixture of petrol vapour and air, of maximum effectiveness. There are two main factors to be considered, viz., the air and the petrol; to obtain a constant mixture under all conditions, we must, therefore, arrange to automatically vary the quantity of one or the other, or both, in order to compensate for the fluctuating demands made upon the carbureter.

Up to the last year or so practically all attempts at rendering a spray carbureter automatic in action have resolved themselves into some system of varying the volume of air passing the jet, whilst at the same time maintaining the cross-section of the latter constant. To this end, adjustable "extra air inlets" were provided in the induction pipe, immediately above the jet, whereby the quality of the mixture could be varied after carburation, either by hand or some automatic device, such as a snifting valve, brought into play when required by the engine suction itself. Although answering the purpose within certain limits, the "ex-

tra air valve," as it is called, is but a crude method of correcting carburation, and, even with the best design of air valves, labours under the disadvantage of a perceptible lag in its action, due to the inertia of the moving parts.

The automatic adjustment of the air supply in its relation to a fixed petrol delivery is effected more

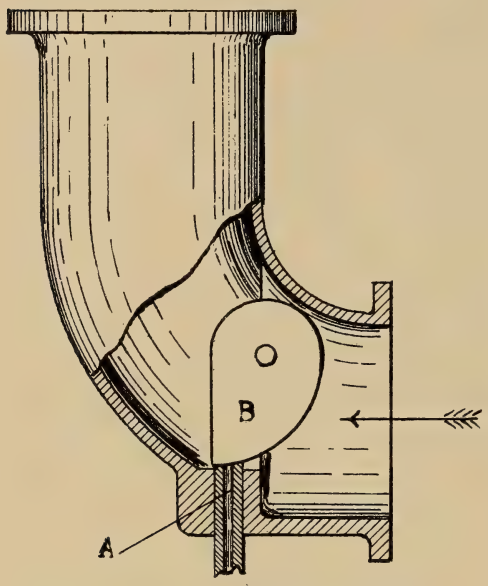


FIG. 2.—THE 1906 MERCEDESE CARBURETER

elaborately in the 1906 Mercedes carbureter, the general principle of what is outlined in Fig. 2. *A* is the spraying nipple, which, it may be here mentioned, can be varied as to the cross-section of its opening by a species of fixed needle valve, capable of very fine adjustment. This adjustment, once made, is, of course, permanent, being provided with the object of enabling an exact proportioning of petrol and air to suit the engine, to be effected at the outset. The velocity of the incoming air past the jet *A* is automatically regulated by a swinging cam-shaped baffle *B*, controlled by a reacting spring, which tends to restore it to a position where maximum concentration of the air upon the jet is secured. The air passage is formed on the one part by the fixed inner wall of the carbureter casing, and on the other by a deep concave groove in the curved surface of the swinging baffle *B*. It will thus be seen that, as the latter swings round under the influence of the engine suction, the cross-sectional area of this air intake is increased, and the consequent injector action upon the jet proportionately reduced. The higher the engine speed, the greater the displacement of the baffle, the inertia of the latter and its controlling spring being so proportioned as to maintain constant carburation within fairly wide limits. In the 1904 pattern of Longuemare carbureter, a similar method of baffling the air supply was adopted, although its action upon the jet itself was less direct than in the case of the foregoing. In the Longuemare carbureter, a rectangular, gravity-controlled shutter was located in the main air intake, its dimensions being such as to practically close the aperture when hanging vertically. This shutter was displaced from its position more or less, according to the engine suction, thus automatically varying the cross-section of the main air passage, which was additionally contracted around the jet by the usual choke tube or funnel shown in Fig. 1.

In the new Brooke carbureter, which also aims at automatic control of the air supply, a fixed air inlet governs the volume of air actually passing the jet, the richness of the resultant mixture being subsequently toned down by mixture with additional air, the quantity of which latter is controlled by a small supplementary piston and valve. The principle is illustrated in Fig. 3, where *A* is the jet and *B* the main air intake, contracted around it as shown. From a point in the induction pipe immediately opposite the jet a branch pipe *C* leads to a small air chamber, or cylinder *D*, within which works a piston *E*, controlling the extra air ports *a a*. Normally these ports are closed, but, as the engine suction increases, so does the vacuum around

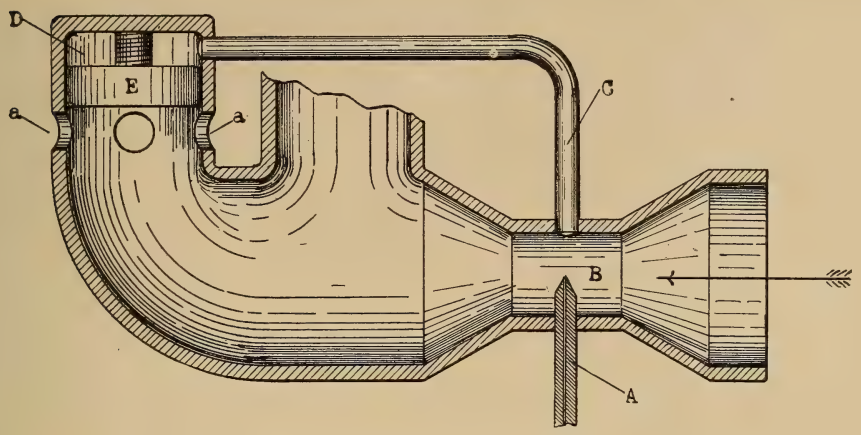


FIG. 3.—THE BROOKE CARBURETER

the jet, and this area being in direct communication with the cylinder *D*, through the pipe *C*, a corresponding pull is exerted upon the piston *E*, thus tending to open the ports *a a* and supplement the air supply.

From the few examples already enumerated, which are typical of many similar devices of varying effectiveness, it will be seen that the intensity of the injector action in a spray carbureter hinges largely on the varying degrees of vacuum produced by the suction of the engine in the neighbourhood of the spraying nipple. This fact has suggested to more than one designer the practicability of governing carburation purely and simply by drawing a suitable balance between the diminished air pressure at this point and that acting on the surface of the petrol in the float chamber, tending to force the petrol through the spraying nipple.

The idea was originally embodied in the Grouvelle and Arquembourg spray carbureter, patented as far back as 1903, but never, so far as the writer is aware, put into commercial use. Referring to Fig. 4, which is a sectional diagram of this device, it will be seen that the float chamber *A*, and that portion of the induction pipe immediately surrounding the spraying nipple *B*, are in direct communication through the medium of the pipe *C*, which thus tends to equalize the atmospheric pressures at these two points at all times. The plug *D*, in the lid of the float chamber, is removable, and can be replaced by others of varying bore, thus providing a means for permanent adjustment of the device in the form of a species of leak valve, the plug being open to the atmosphere. A further adjustment suggested in the patent specification consists in the provision of a removable plug or adjustable tap in the pipe *C* as a means of varying its internal diameter, and thus modifying the pressure balancing effect.

During the last few months this principle of governing carburation by balancing the respective air pressures at the spraying nipple and in the float chamber has been embodied in a patented attachment for fitting to existing spray carbureters by Messrs.

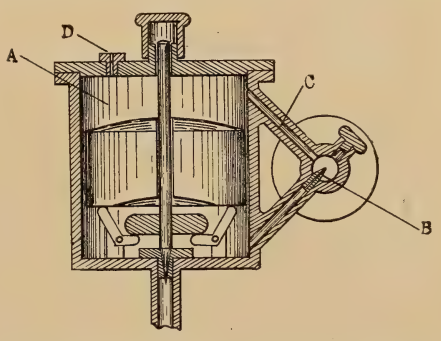


FIG. 4.—THE GROUVELLE AND ARQUEMBOURG SPRAY CARBURETER

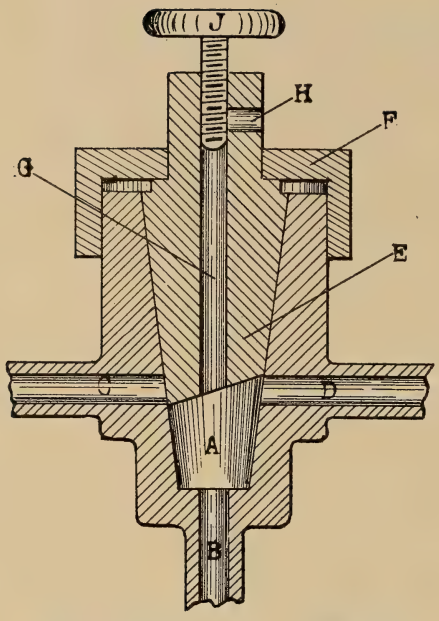


FIG. 5.—THE GILLETT-LEHMAN CARBURETER

Gillett & Lehmann, who have made a special study of the subject. The Gillett-Lehmann device goes a step further than the original Grouvelle & Arquembourg carbureter, in that it provides also a means for suitably balancing the pressures on either side of the throttle valve, which, as a little consideration will show, may, and in practice undoubtedly do, differ by quite a considerable amount when the throttle is nearly closed. The general principle of the Gillett-Lehmann carbureter controller is indicated graphically in Fig. 5, where *A* represents a small air chamber, common to three passages, *B*, *C* and *D*, communicating with the float chamber, jet and engine sides of the throttle, respectively. *E* is a taper plug kept down on its seating by the locking cap *F*. Down the centre of this plug extends an air passage *G*, which communicates with the atmosphere at *H*, the extent of the opening being controlled by the milled adjusting screw *J*, which can be screwed down to such an extent as to completely close the aperture, thus rendering the system air-tight. The lower end of the taper plug *E* is bevelled off, as shown, the line of bevel extending between the limits of the apertures *C* and *D*. It will thus be seen that, by turning the plug *E* on its seating, the relative openings of *C* and *D* can be conveniently varied. The initial setting of the device for a given engine and carbureter is as follows: Assuming the screw *J* to be so adjusted as to completely interrupt communication with the atmosphere, the taper plug being so set that *C* and *D* are both equally open, the pressures on either side of the throttle and in the float chamber will be equal, and no petrol will pass through the spraying nipple; consequently the engine will not start. The screw *J* is, therefore, adjusted so as to allow just so much air to enter as will enable the engine to run smoothly at its normal speed. Next, the taper plug *E* is turned on its seating in such a direction as to partly close the orifice *C* leading to the jet side of the throttle valve, until the engine misfires at low speeds; this effect having been secured, it is turned back slightly, until misfiring ceases and the engine runs well at slow speeds. The plug *E* is then locked in position by screwing down the cap *F*, and the engine tried under load, when, if it be found that more power is required, the air inlet is slightly enlarged by unscrewing *J* half a turn or so, until the required effect is secured. Assuming all other portions of the carbureter to be air-tight, no further adjustment is necessary, and a material improvement in the carburation at all speeds and loads should result. Theoretically, this device should go far towards solving the problem of perfect automatic carburation, in that there are no moving parts, but instead a direct communication between the three points most vitally concerned, viz., the jet and float chambers and induction pipe, the two passages *C* and *D* serving to annul the disturbing effects of variable throttle opening. The inventors, Messrs. Gillett & Lehmann, have since introduced a complete carbureter em-

bodying this principle, the results of practical tests of which will be awaited with considerable interest by automobile engineers.

All the carbureters so far described have depended upon the variation of the air supply alone for maintaining a correct mixture, and we will now proceed to deal with one or two leading types in which regulation is effected by controlling the quantity of petrol passing the jet as well. The White & Poppe carbureter is a very good example of this system, its acting principle being embodied diagrammatically in Fig. 6, where *A* is the spraying nipple, projecting up axially through the centre of the cylindrical jet chamber, and communicating with a float chamber, whence it derives its fuel supply in the usual manner. As shown in the figure, the upper surface of the nozzle is conical, thus providing a close and well ground-in seating for the cylindrical combined air and throttle valve *B*, which is kept in place by pressure of the light spiral spring *C*. The spraying orifice, which has a cross-sectional area of 0.001 square inch, extends through both spraying nipple *A* and the shell of the internally coned valve which rests upon it, and is drilled slightly out of centre. It will thus be seen that the two openings are only in exact alignment for one position of the circular air and throttle valve, which corresponds with open throttle. When this valve is turned about its axis, the two orifices fail to exactly coincide, until, at a point corresponding with closed throttle, they are no longer in communication and the petrol passage is completely closed. The air inlet is similarly controlled by turning the combination valve on its seating, the disposition of the parts being such that, whatever the radial position of this valve, the ratio between the size of the spraying nipple and the air inlet remains constant, thus insuring regular explosive mixture at all adjustments of the throttle valve. Provision is also made in this carbureter for adjusting the main air supply in conformity with the atmospheric pressure and humidity on any given day in the shape of a circular sleeve, not shown in the figure, which fits round the outer circumference of the throttle, and is pierced with a number of holes or air ports, the extent of whose opening can be set by hand at the commencement of a day's run. It is claimed for this carbureter that it is particularly conducive to smoothness and silence of running, and the writer's experience confirms this view, a certain car fitted with the device running at all speeds and loads with an entire absence of the sucking noises usually associated with aspiration carbureters.

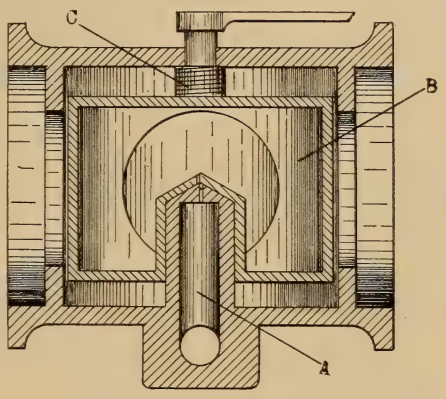


FIG. 6.—THE WHITE & POPPE CARBURETER

Another method of attaining the same object, viz., constant proportioning of the air and petrol for all openings of the throttle valve, is by a combination of jets and air ports, in what are known as multiple-jet carbureters, which are necessarily somewhat more complicated in their construction than the single-jet variety. There are several makes of carbureter embodying this principle, in which two or more jets are employed and brought into action, either singly or in combination, according to the demand made upon them by the engine. One of the latest and most promising patterns is the T. & M. triple-jet carbureter, made by Messrs. Trier & Martin, Ltd.

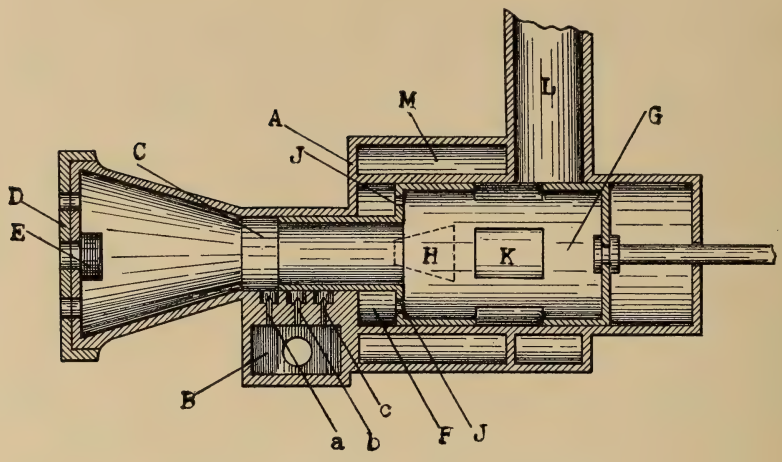


FIG. 7.—THE TRIER & MARTIN CARBURETER

It is represented in Fig. 7, where *A* is the main body of the carbureter, above a small petrol chamber *B*, in which are disposed the three spraying nipples *a*, *b* and *c*. The reservoir *B* is fed with petrol from a float chamber of the ordinary type, and the nipples open into a contracted portion of the spraying chamber *C*, one end of which expands into a funnel-shaped opening or air inlet, controlled by a revolving shutter *D* and automatic air valve *E*, consisting of a closely coiled wire spiral, the turns of which open out under high engine suction and thus act the part of an extra air valve. At its other extremity the chamber *C* expands into a cylindrical casing *F*, of larger diameter, which encompasses the piston throttle *G*, and has openings *H* in its walls communicating with the atmosphere, all air entering through which is diverted through the openings in the throttle piston shown at *J*, *J*. This piston throttle also has two diameters, corresponding with the internal bores of the casings *C* and *F*, and is provided with ports *K*, which communicate with the inlet pipe *L* when the throttle is opened. Surrounding the larger chamber *F* is a hollow jacket *M*, which is heated either by hot water from the radiator or a by-pass from the exhaust. Opposite each of the three jets *a*, *b* and *c* are small holes, extending through the walls on either side of the casing *C*, which serve to modify the intensity of the injector action upon the jets in process of opening the throttle, and thus prevent the mixture from becoming overrich in petrol. The revolving shutter *D*, which is adjustable, serves as a means of setting the carbureter to the engine in the first instance, after which adjustment it is locked in position. With only one jet *a* in action, the whole of the air supply enters through this shutter and by way of the two small orifices opposite that jet. When the throttle is opened so as to uncover jet *b*, the angular air port *H* is also practically uncovered by the throttle piston, and wholly opened with the simultaneous uncovering of jet *c*. Beyond this point there is still a final means of ingress for air by way of the coiled spring air valve *E*, which comes into action at high engine speeds and with throttle full open, in which latter position all three jets are uncovered, and the openings *K*, in the piston throttle, in full communication with the inlet pipe *L*.

A final example of combined air and petrol regulation is provided by the Xenia carbureter, which embodies several novel features in its construction. The base of the jet chamber

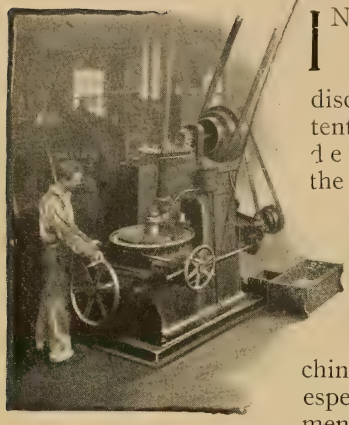
comprises a mercury reservoir, upon the surface of the mercury in which is supported a float which, in turn, carries the jet tube, and above this again an automatic air valve. The jet tube and air valve are free to move vertically within a fixed tube, slots in the side of which latter afford communication with the jet orifices, several of which are drilled at various heights in the jet tube and become operative according to the relative position of this latter in the fixed sleeve. The engine suction determines the position of both air valve and attached jet tube, and consequently the relative supplies of petrol and air. The mercury, which is prevented from oxidizing by the petrol above it, acts in the capacity of a dash-pot to the moving parts of the device.

In conclusion, the writer would again emphasize the fact that the various carbureters described in the foregoing article have been selected without prejudice to the remainder from a large number of designs of varying efficiency, all of which, however, are based upon similar fundamental principles, and, in justice to the remainder, it is only fair to add that there is, at present, no "best" carbureter, each one having its own particular merits and demerits, the practical success of one carbureter and the failure of another being more often than not dependent upon the vagaries of the particular engine with which they are employed.

The solution of the problem of perfect automatic carburation, in spite of the vast improvements which have been effected during the past decade, is yet far removed from finality, and affords a most interesting field for investigation and research, which is rendered all the more attractive by the possible future restriction of our available petrol supply and the consequent enforced substitution of other liquid fuels.

MACHINE TOOLS FOR GAS ENGINE CONSTRUCTION

II.—RECENT AMERICAN MACHINE TOOLS



IN the last issue of this magazine there was discussed the extent to which the development of the gas engine industry had reflected its activity upon the design and modification of machine tools for that especial department of work in the machine shop, and numerous illustrations were given of recent machine tools particularly adapted for shops devoted to the construction of internal-combustion engines, these examples being taken principally from British practice.

Although the development of the large gas engine has been later in the United States than in Europe, and is, in fact, only beginning to demand special consideration, it has already had its effect upon the design of the tools employed. Often there is no material change in design of the machine itself, but simply the provision of additional details, special tools, or the extension of attachments already in use; but in other cases there has been a material modification of the whole machine to adapt it to the especial requirements of the work.

The ordinary stationary gas engine of moderate size requires little or no special work. With the exception of the rods, cranks, shaft, etc., the parts are principally of cast iron, and machined in much the same manner as similar parts of steam engines. The parts are usually designed in a more massive manner than is customary with steam engines of the same power, since the distribution of effort is not so uniform with the gas engine, and the liability to shock from pre-ignition and back-firing must be considered and provided for.

With the large gas engine there are a number of parts of large size, including portions of the frame, cylinders, crankshafts, etc., which require accurate machining upon heavy tools, and for such work the modern planers, lathes, milling machines, and the like, must be used. While it is impracticable to examine in detail such standard tools as these, mention may be made of some notable examples in passing.

One department of combustion-engine construction, however, has made special demands upon the machine-tool builder and operator, that involving the production of the small-size, high-power gasoline engines for automobiles, and for such work there are several questions demanding attention.

In the first place, lightness is essential, while at the same time the liability to shock and sudden excessive stress must be provided for. Both of these requirements exclude cast iron whenever it can be replaced by wrought metal and forged steel. Drop-forgings and stamped and pressed sheet metal are employed wherever practicable. The frames of automobiles are often made of pressed steel, this work requiring a heavy press, while the drop-forging press is becoming more and more widely employed for forging multiple crank

ATLAS DROP-FORGING COMPANY, LANSING, MICH. STEAM DROP HAMMERS FOR AUTOMOBILE PARTS

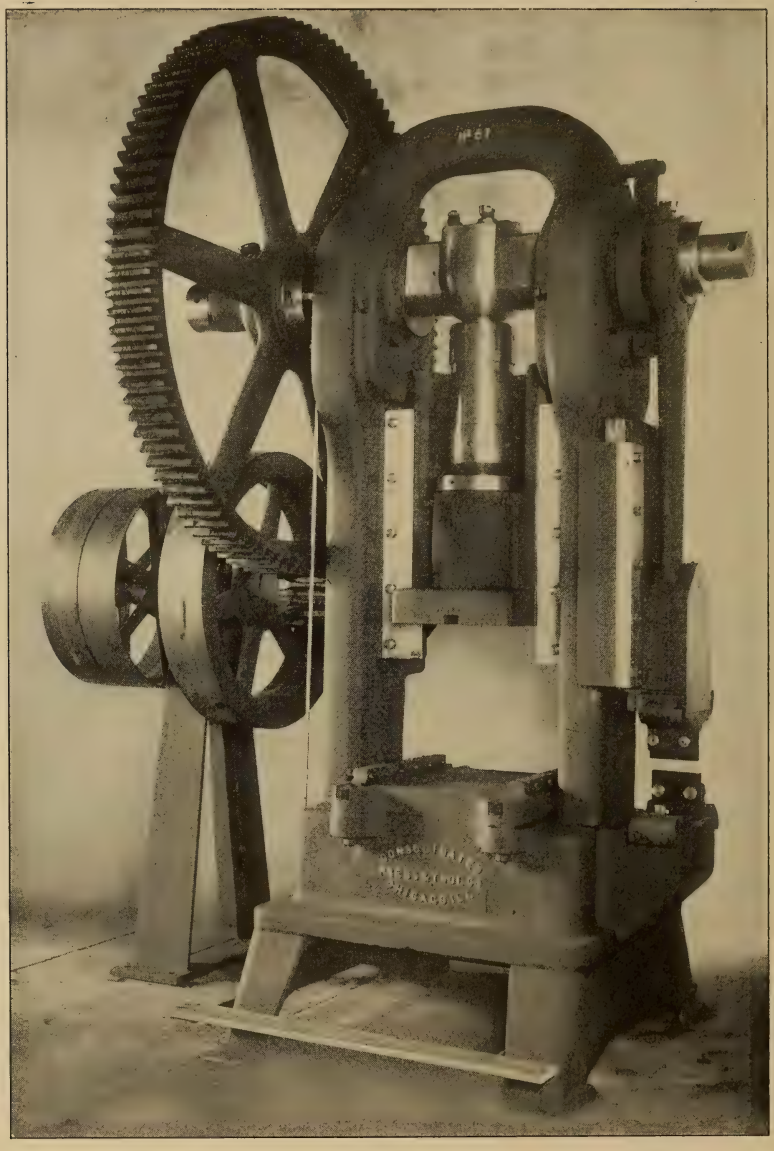
axles, formerly forged solid under the hammer and cut out. The steam hammer or drop press is also used extensively, however, and both types of machine find abundant opportunity in this department of service.

In connection with the manufacture of multiple crankshafts for automobile engines, the grinding machine is being largely employed for finishing, and in this manner highly finished surfaces and accurate dimensions are secured, together with rapidity in repetition, production and consequent reduction in cost.

For the finishing of gas engine trunk pistons various forms of turret lathes are extensively employed, together with grinding machines for the completion of the work. Grinding machines are also employed for finishing many of the smaller parts, and the modern gas engine may be considered as an excellent representative of the product of the latest machine-shop methods in all its parts.

The following examples are selected from the products of representative makers, and will serve to show the general trend of practice at the present time.

In the forging of parts for automobiles and gas engines the hammers employed are either of the ordinary drop type or are steam drop hammers. Of the latter class several machines shown are built by the Chambersburg Engineering Company, Chambersburg, Pa., these machines being used for making axles and large crankshafts from vanadium and chrome steel, the forgings being made in one piece without any welding or bending. These machines are made double-acting, taking steam top and bottom, and are arranged with adjustment of the frame on the anvil to facilitate the setting of the dies. With such machines the output is very materially increased over the



STRAIGHT-SIDED PRESS, DESIGNED FOR FINISHING GAS-ENGINE CRANK SHAFTS. CONSOLIDATED PRESS & TOOL CO., HASTINGS, MICH.

older type board drop hammers. Hammers of this type are very extensively employed, the smaller size being used for forging steering knuckles, transmission gears and similar parts.

A general idea of the manner in which the drop press is employed in the forging of crankshafts and similar parts for combustion engines is obtained from the views of the drop-forging department of the Atlas Drop Forging Company, at Lansing, Mich., equipped by the Consolidated Press & Tool Company, of Hastings, Mich., especially for the production of parts for automobile and standard gas engines. Among the machines shown

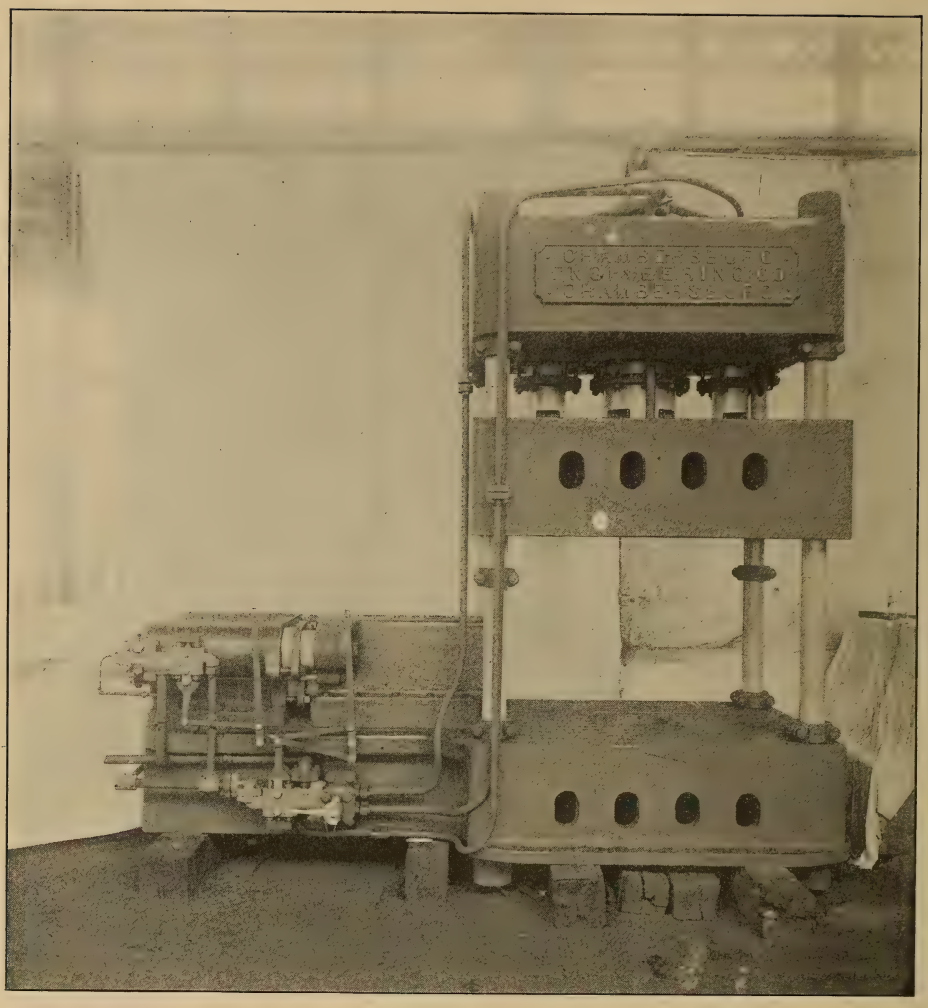
in these illustrations will be observed a heavy hydraulic press, capable of exerting a pressure of 3,000 tons, while the steam drop hammers, trimming presses and heating furnaces are also shown, as well as forgings in different stages of completion. This plant is an excellent example of the influence of the development of the gas engine upon machine-shop work, the equipment of this shop having been especially designed for the commercial production of gas-engine and automobile parts, and representative of the latest tools of the kind.

Hydraulic presses are extensively used in pressing steel parts for automobile frames and the like, and among the tools of this kind there are shown presses built by the Chambersburg Engineering Company. A geared press by the same builders is also shown, as well as a heavy power press by the Ferracute Machine Company, of Bridgeton, N. J., this latter machine weighing 50,000 pounds, and capable of exerting a pressure of 500 tons.

Standard drop presses are in very general use for producing forgings for combustion engines, and the machines of the Billings & Spencer Company, shown in the illustrations, are typical of this useful class of machines.

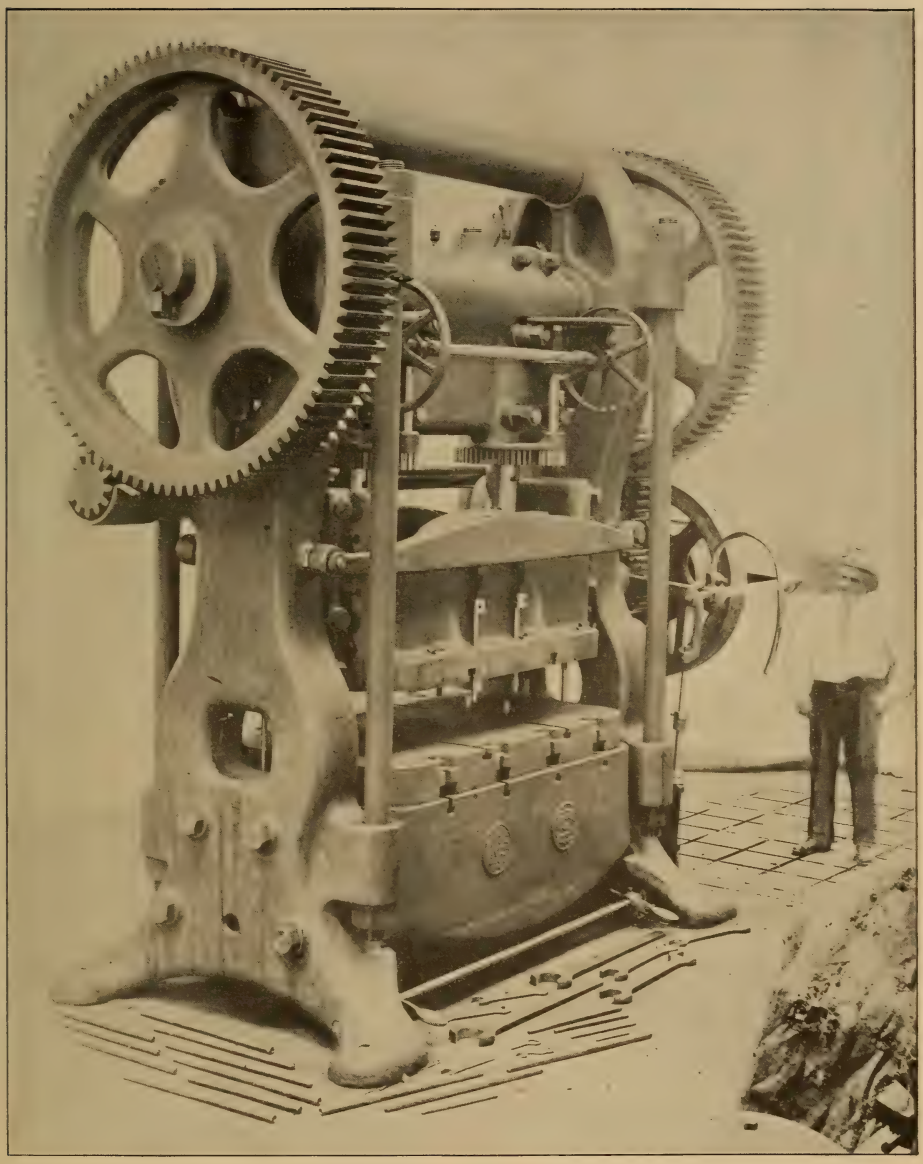
In finishing gas engine parts attention must be given to the special problems which have to be met. In the smaller sizes of engines the use of several cylinders is general, in order to obtain a more uniform turning moment than is possible with a single cylinder. Six-cylinder motors are coming into very general use for automobiles, and this means that corresponding multiple crankshafts have not only to be forged, but turned and finished. A special lathe for finishing the bearings and crank-pins of

ATLAS DROP-FORGING COMPANY, LANSING, MICH. HAMMERS, TRIMMING PRESSES AND FURNACES



HYDRAULIC FORGING PRESS FOR AUTOMOBILE PARTS. CHAMBERSBURG ENGINEERING COMPANY

such shafts is that known as the Tindel-Albrecht lathe, built by the Tindel-Morris Company, of Eddystone, Pa. The ordinary method of turning such shafts involved the use of driving disks on each end of the shaft, these disks containing centres corresponding to the central lines of the various cranks to be turned. This method, which originated with the plan formerly devised for large and heavy shafts, has the difficulty, when applied to light crankshafts, that the power must be transmitted through the shaft itself to the point at which the tool is acting, and the spring of a light shaft is objectionable. In the Tindel-Albrecht lathe the shaft is not only supported and driven at both ends, but it is also supported and driven at the very point where the cutting is being done. This desirable result is effected by the use of a movable driving mechanism, capable of adjustment so as to be placed close to each crank-pin and bearing as it is turned. A driving shaft placed at the back of the lathe carries pinions gearing into driving gears attached to the shaft to be



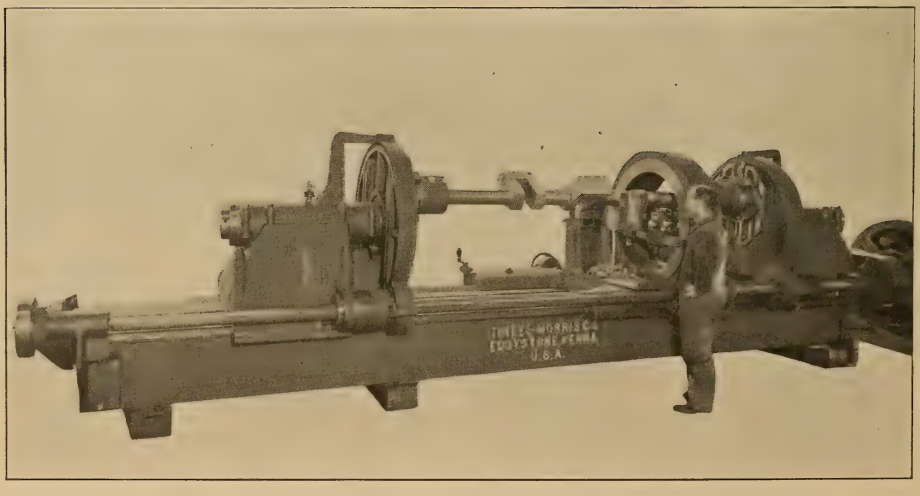
GEARED POWER PRESS, 500 TONS CAPACITY. FERRACUTE MACHINE CO., BRIDGETON, N. J.

turned, and in this manner the transmission of power through the crankshaft itself is avoided and all tendency to spring is eliminated.

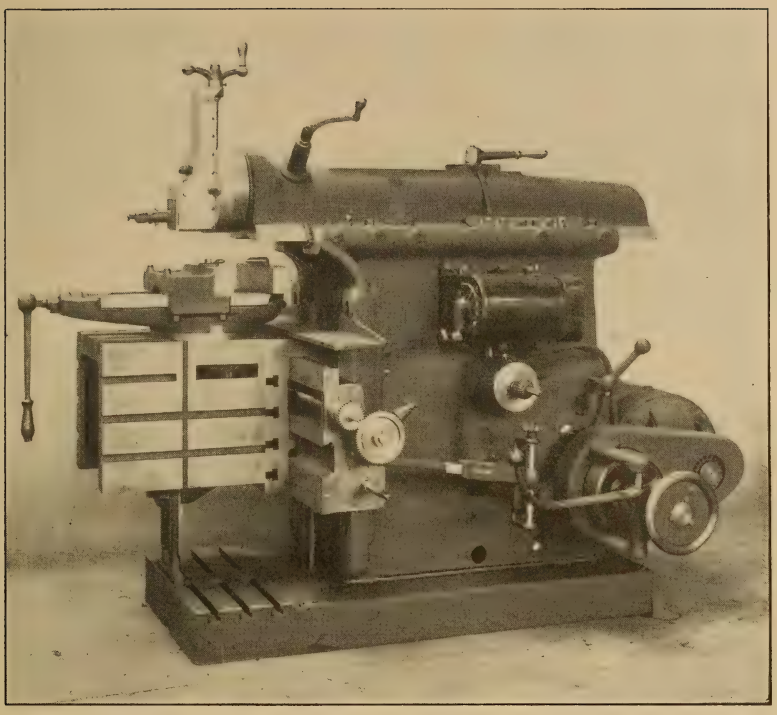
The use of the grinding process for finishing multiple crankshafts is extending, especially in view of the fact that hardened shafts are coming into use. Such shafts naturally demand the grinding machine for their finishing, and indeed it is maintained by some that the grinding process is the only one by which truly cylindrical pins and journals can be produced. In the design of such machines it is essential that there should be freedom from vibration, this demanding weight materially in excess of that required

HYDRAULIC FORGING PRESS, STEAM HAMMERS AND TRIMMING PRESS AT THE ATLAS SHOPS

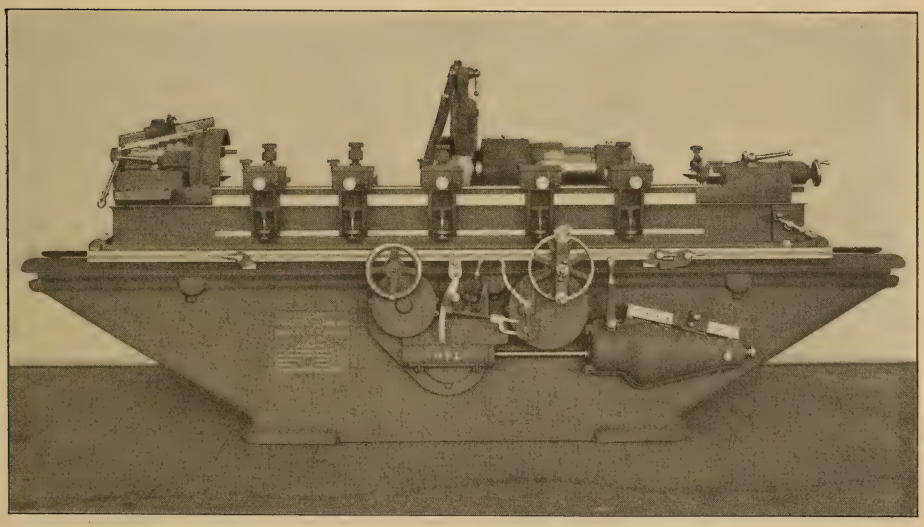
merely for strength. The truth of the spindles is a matter of much importance, since upon this depends the accuracy of the product. An especial feature in all grinding machinery is the protection of the wearing parts of the machine from its own grit, a detail to which much attention has been given. We give in the illustrations examples of external and in-



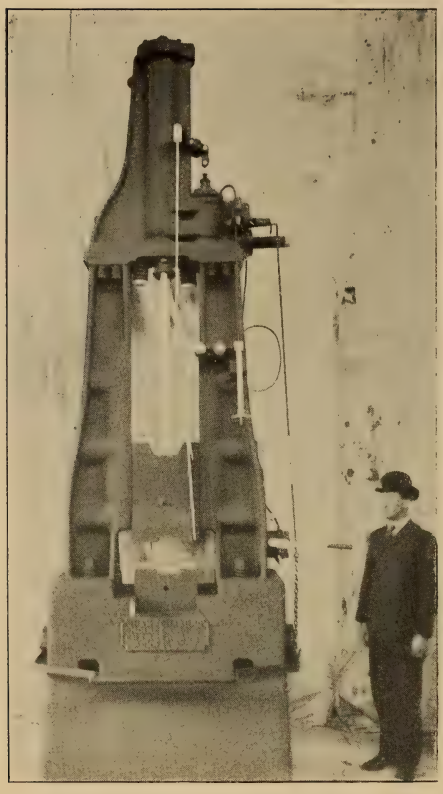
THE TINDEL-ALBRECHT CRANK-SHAFT LATHE. TINDEL-MORRIS COMPANY, EDDYSTONE, PA



HIGH-DUTY SHAPING MACHINE WITH DIRECT-CONNECTED ELECTRIC DRIVE. GOULD & EBERHARDT, NEWARK, N. J.



NORTON GRINDING MACHINE FOR CRANK SHAFTS. NORTON GRINDING COMPANY, WORCESTER, MASS.

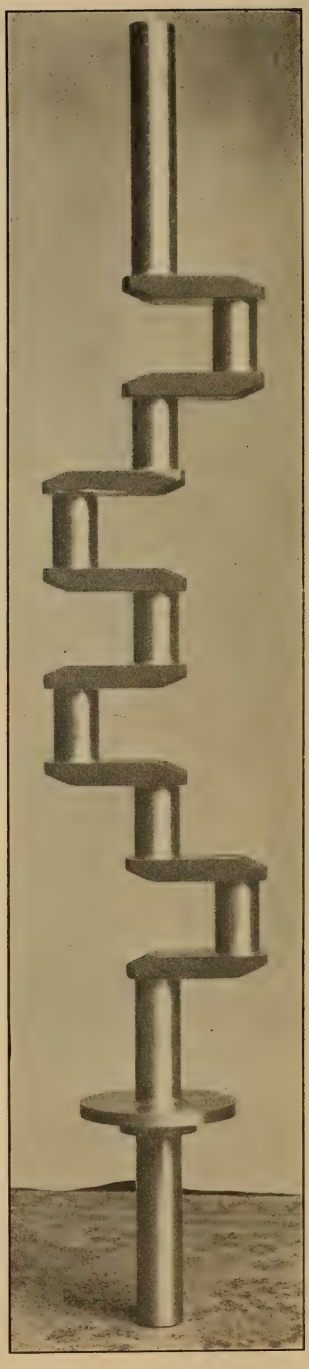


STEAM DROP HAMMER. CHAMBERSBURG ENGINEERING COMPANY

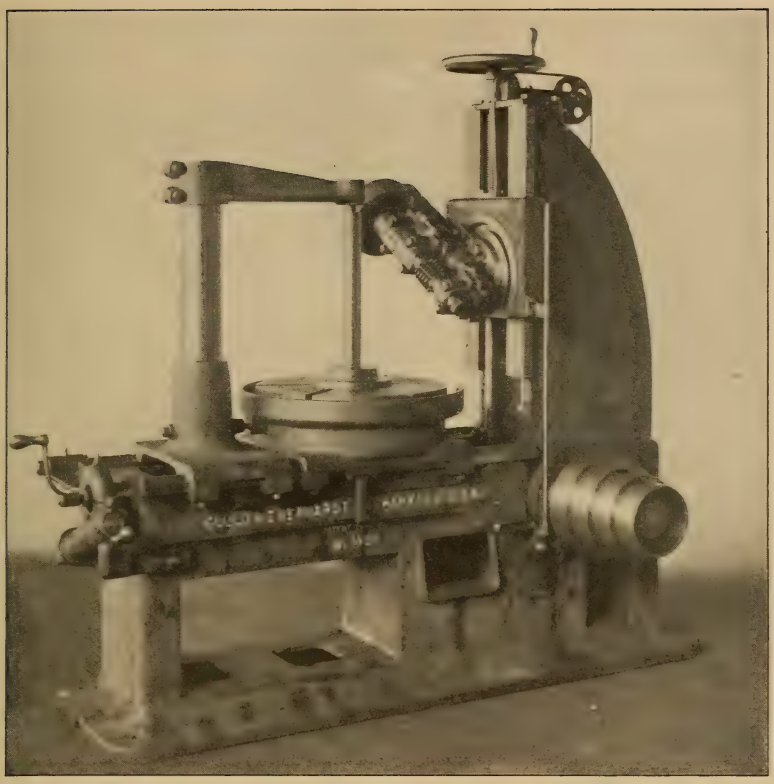
ternal grinding machines built by the Landis Tool Company, of Waynesboro, Pa., and of the Norton Grinding Company, of Worcester, Mass., together with an illustration of a four-throw crankshaft as finished by the Norton Company.

Grinding machines are also arranged for internal finishing, such as the cylinders of automobile engines and similar parts, and the grinding wheel is rapidly extending its position from that of an abrasive to that of a legitimate cutting tool.

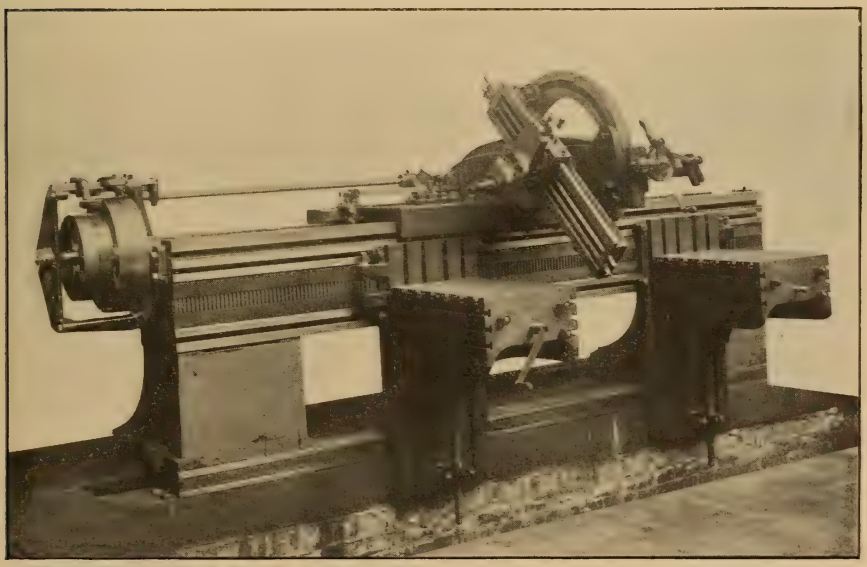
A few gear wheels are employed in the construction of combustion engines, the four-cycle engine demanding a speed reduction of one-half between the revolutions of the crankshaft and the valve-motion shaft, and this reduction is effected by bevel gears, or often by spiral gears. In



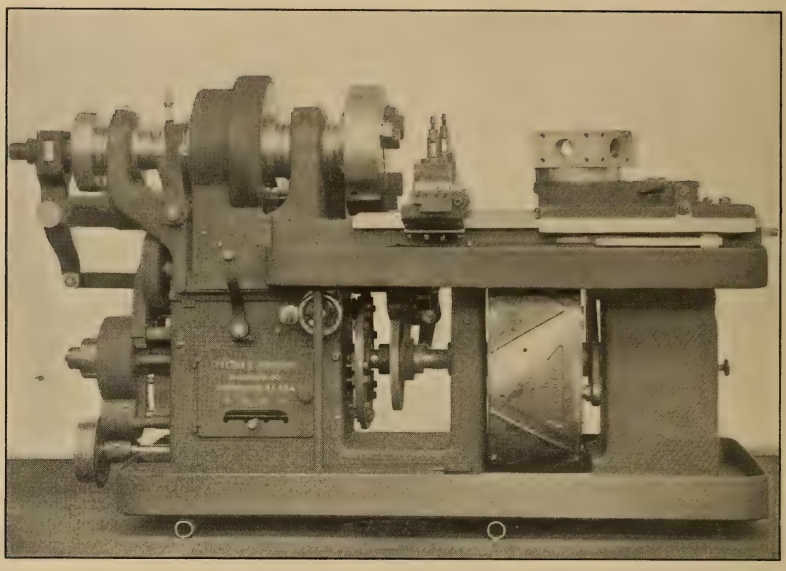
FOUR-THROW CRANK SHAFT. FINISHED ON NORTON GRINDING MACHINE



GEAR CUTTING MACHINE FOR SPUR, WORM AND SPIRAL GEARS. GOULD & EBERHARDT, NEWARK, N. J.



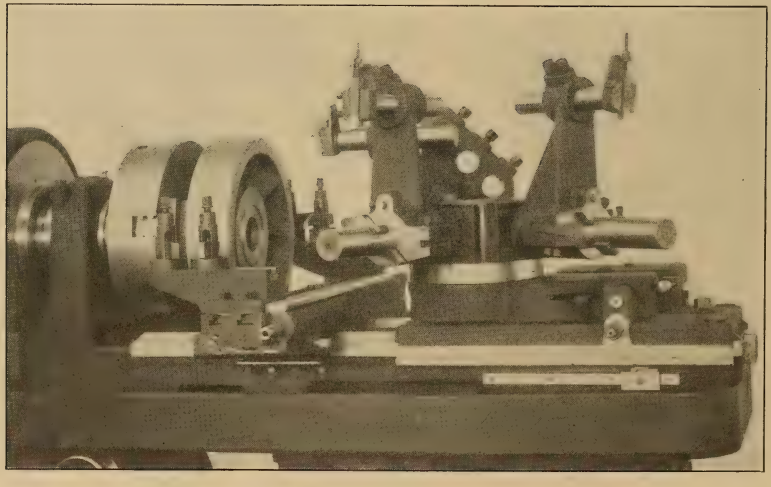
SIDE PLANING MACHIME. GEORGE RICHARDS & CO., MANCHESTER



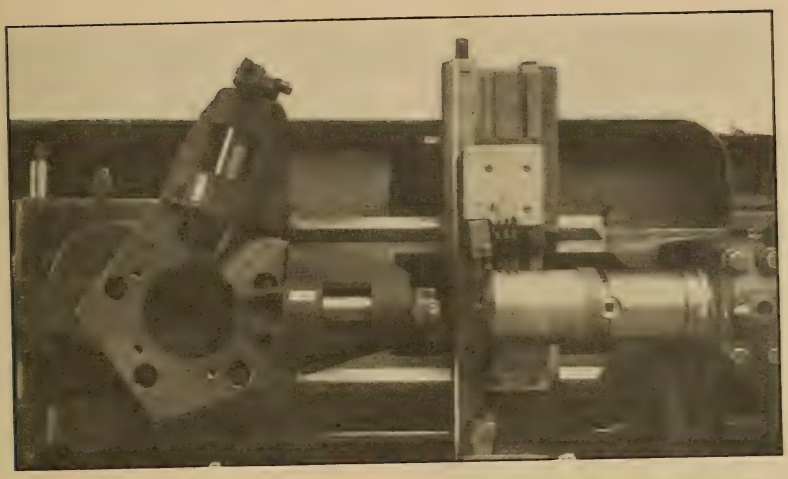
AUTOMATIC CHUCKING AND TURNING MACHINE. POTTER & JOHNSTON MACHINE CO., PAWTUCKET, R. I.

the case of the larger engines gear wheels have also been used to offset the valve shaft, especially in large tandem engines. Smoothness of action demands that these gears be cut, and hence gear-cutting machines come into service in gas-engine building, but the conditions are not greatly different from other applications of gearing, and no modification in the machines has been found necessary.

Reference has been made to the fact that large gas-engine frames and bed-plates require the use of correspondingly effective planing machines for finishing, and in this connection attention may be called to an especially large and powerful planer, built by the Niles-Bement-Pond Company at their Philadelphia works. This machine, which was built for a prominent firm of builders of steam

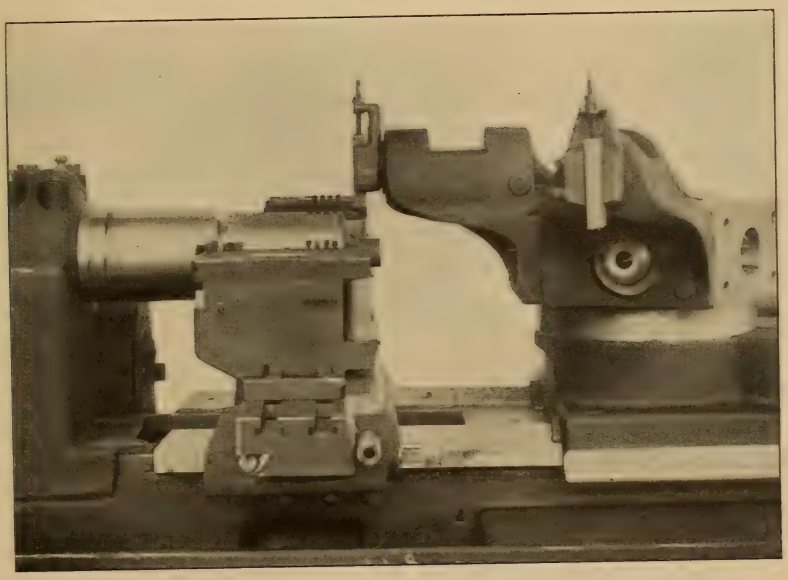


MACHINING GAS-ENGINE FLY-WHEEL ON POTTER & JOHNSTON CHUCKING MACHINE

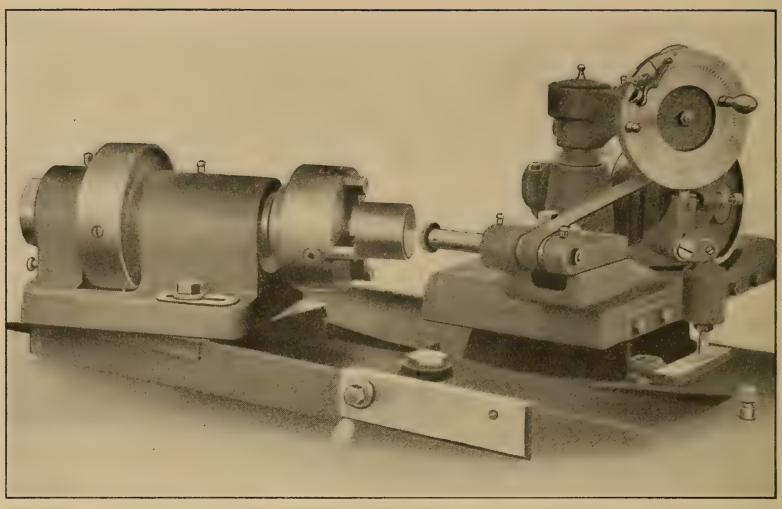


TOOLING ARRANGEMENT FOR MACHINING GAS-ENGINE PISTONS ON POTTER & JOHNSTON CHUCKING MACHINE

engines and heavy machinery, is claimed to be the largest planing machine yet constructed, as it weighs 845,000 pounds and requires more than 200 horse-power for the operation of its various parts. The machine is 14 feet 4 inches wide between the uprights, with a travel of 30 feet for the table, and a maximum height of 12 feet 2 inches under the rail. The operative functions of the planer are driven electrically, a motor of 100 horse-power being used to drive the table, while a 50 horse-power motor operates the slotting and cross-planing motion, and one of 20 horse-power raises and lowers the cross rail. The various movements are controlled by clutches operated by compressed air, and the whole design of the machine is to be commended as involving a high degree of



TURNING, GROOVING AND FACING GAS-ENGINE PISTONS ON POTTER & JOHNSTON CHUCKING MACHINE

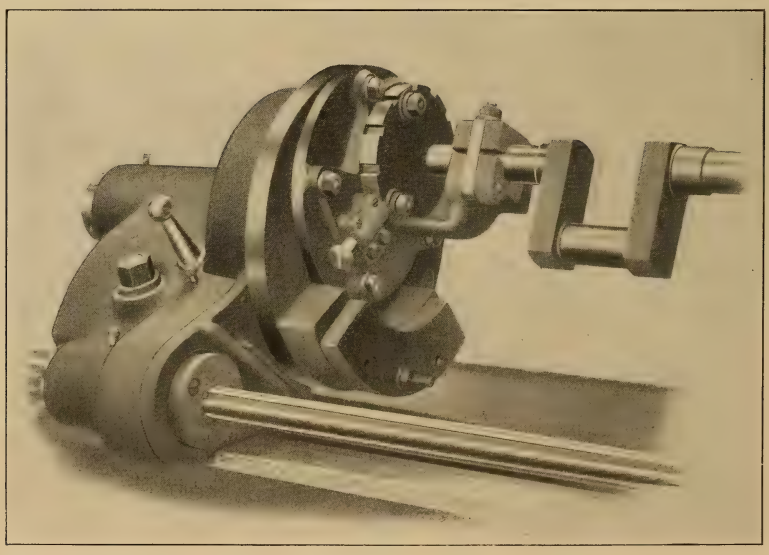


INTERNAL GRINDING MACHINE FOR TAPER OR CYLINDRICAL WORK. LANDIS TOOL CO., WAYNESBORO, PA.

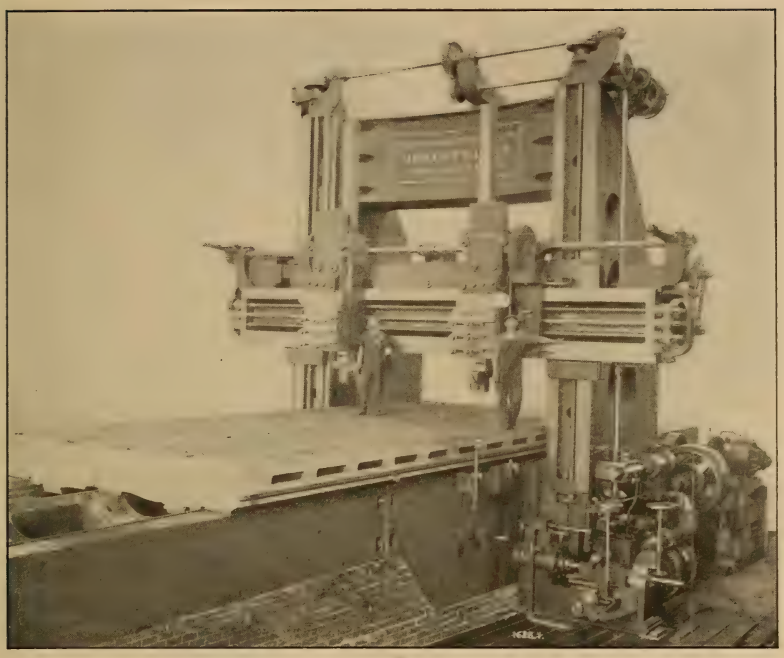
mechanical refinement combined with great size and massive strength.

An altogether different machine, and one which is well known on both sides of the Atlantic as a most useful form of planing machine, is the side planing machine, built by George Richards & Co., of Broadheath, near Manchester, England. This machine has been found very useful in finishing the frames of gas engines of moderate size, as well as for much general work of the sort, and it practically fills a place between the heavy planer of the older type and the shaping machine, both of which are essential tools in the shop which undertakes gas-engine construction.

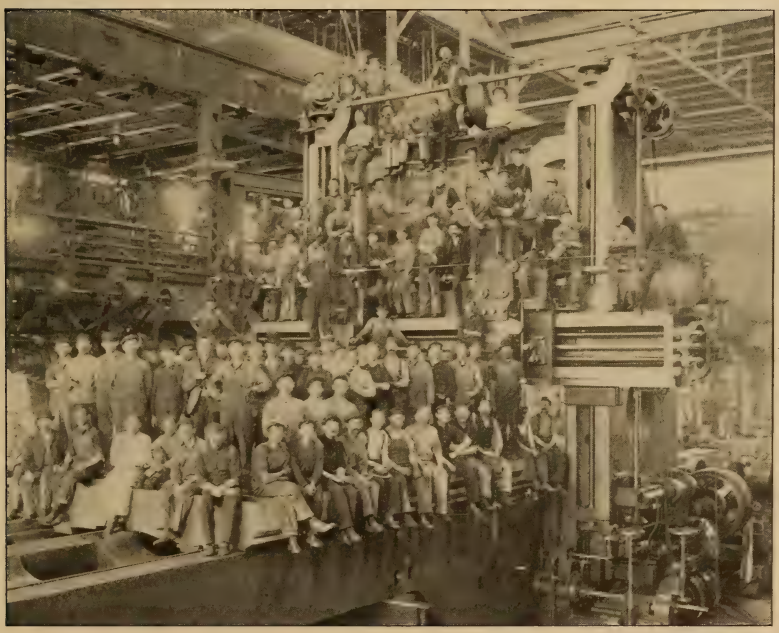
The machines thus mentioned and



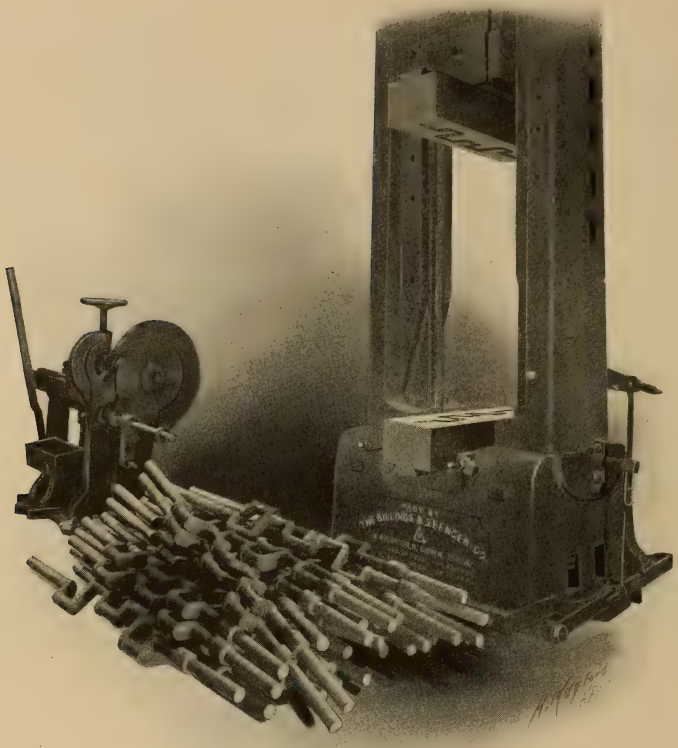
ADJUSTABLE HEAD FOR CARRYING CRANK-SHAFTS DURING GRINDING. LANDIS TOOL CO. WAYNESBORO, PA.



LARGE PLANING MACHINE, ARRANGED WITH ELECTRIC DRIVE AND PNEUMATIC CLUTCHES.
NILES, BEMENT, POND CO., PHILADELPHIA, PA



THE LARGEST PLANING MACHINE YET BUILT NILES, BEMENT, POND CO., PHILADELPHIA



BILLINGS & SPENCER DROP HAMMER FOR CRANK SHAFTS

illustrated are but examples of numerous tools which have been found important in the developing industry of gas-engine building. They represent, however, principles which are included in the tools of many of the builders on both sides of the Atlantic, and which are doing much to render the construction of such a machine as the modern internal-combustion motor commercially practicable.

As was seen in the various articles contained in the Special Gas-Power Number of the magazine last November, the manufacture of such machines practically covers almost the extreme range of machine-shop work. The automobile calls for engines ranging from 5 to 100 horse-power, with one to six cylinders, the power being developed mainly by reason of the high speed of rotation, and all parts requiring a high degree of perfection in manufacture. Still more exacting are the demands for engines for experimental work in aeronautics, a department which may soon be advanced from the experimental stage to that of commercial manufacture. Engines for this work have to meet the same requirements as to perfection as do the machines for automobiles, with the added condition of minimum weight for the power developed, a condition which includes the use of the highest grades of material and the utmost skill in design and workmanship.

The medium-size gas engine, on the contrary, is installed in many places because the demand for power is not sufficiently uniform or con-

stant to warrant the use of a steam-power plant with an engineer in regular attendance, and the combustion motor, by reason of its convenient property of being in immediate readiness for starting, is selected for the work. This very property, however, involves the fact that the machine does not receive the care and attention given to an engine in continual operation, and hence the medium-sized gas engine must be designed to withstand a certain amount of neglect and rough usage, and yet possess the practical virtue of reliability under such different circumstances.

Passing to the large, modern internal-combustion engine, this machine is the natural outgrowth of the discovery of Mr. Thwaite that the waste gases from metallurgical furnaces are applicable for direct use in the engine with but a preliminary cleaning for the removal of dust and impurities. The natural consequence of the practical application of this discovery has been the extension of the gas engine to sizes of 3,000 to 5,000 horse-power, sizes which involve much more difficult problems in design and manufacture than are encountered in building steam engines of equivalent power.

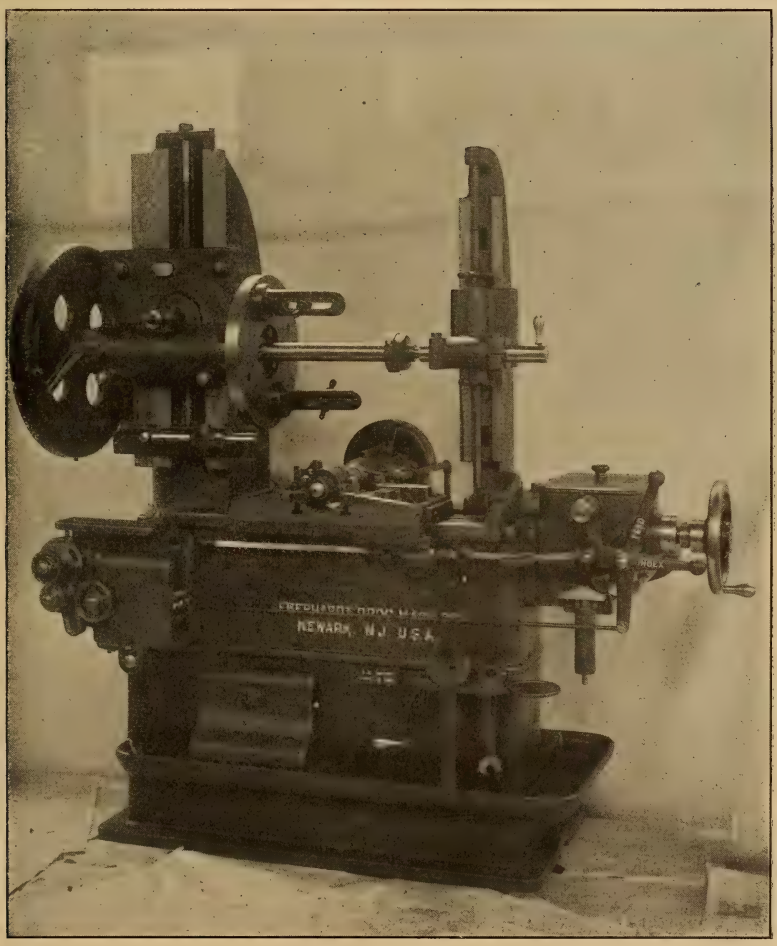
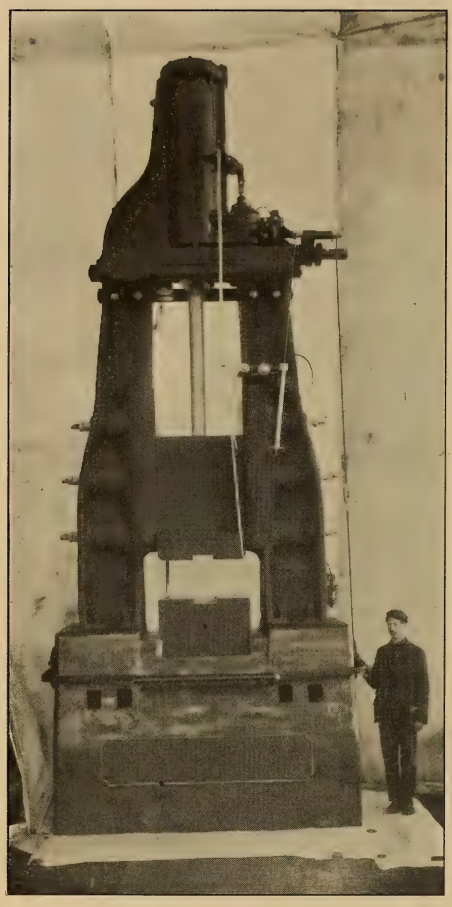


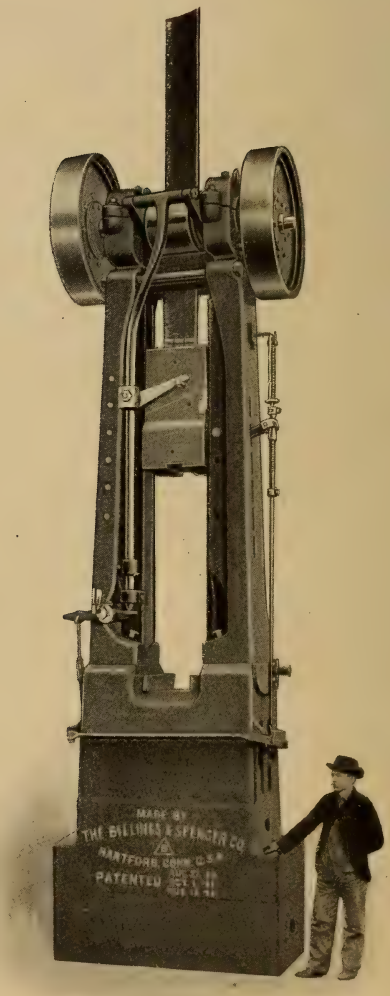
FIG. AUTOMATIC GEAR-CUTTING MACHINE. EBERHARDT BROS. MACHINE CO., NEWARK, N. J



STEAM DROP HAMMER. CHAMBERSBURG ENGINEERING COMPANY

This wide range of requirements in construction involves a correspondingly extensive scope in the question of the machine tools by which the various kinds of internal-combustion engines are to be built. At the present time the work is naturally being distributed among different establishments, in accordance with the nature of the product, and it is probable that this differentiation will continue and become even more marked and specialized. A corresponding specialization in machine tools will probably follow, so that the tendencies in their design, as indicated in these articles, will become more distinctive during the next few years.

It has been shown that practically all of the fundamental principles of the combustion motor were well known many years ago, and yet it is but recently that the general manufacture of such machines has grown to industrial importance. This is doubtless due to the fact that the theoretical motor had to wait until the constructive art had caught up with its demands. In this respect the development of the gas engine does not differ greatly from that of many other departments of applied



BILLINGS & SPENCER 3,000 POUND DROP HAMMER

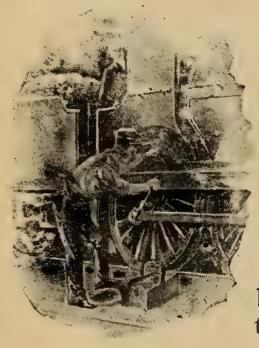
A STODDART-DAYTON CRANK SHAFT. TURNED ON A TINDEL-ALBRECHT LATHE.

science. The original inventor often appears visionary to the practical man because he ignores shop methods and appliances, and conceives a device which can be made but imperfectly at the time, or else at such a cost as to be a commercial failure. Later inventors take up the idea and either modify it in accordance with constructive methods of the time or bring their experience to the design of appliances by which the new machine may be manufactured to advantage. As the limitations of patent restrictions expire, the parallel development of other lines of construction renders the invention attractive to general manufacturers, and such special tools and appliances as are necessary are evolved and a new branch of industry is developed. It is not necessary that the gas engine should supplant the steam engine as a prime mover for it to attain a very important position as a product of engineering manufacture, and there is every reason to believe that for a long time at least both motors will continue to develop side by side, each meeting the demands of commerce and manufactures. It must be conceded, however, that the machine-tool industry is awakening to the magnitude and importance of providing such machinery as may be necessary to permit the manufacture of gas engines of all sizes, from the small and light motor for the automobile or the aeroplane to the heavy and powerful engine utilizing the power of the hitherto wasted gases of the blast furnace, to become the great industry which its commercial possibilities demand.

BRITISH RAILWAY DEVELOPMENT, PAST AND FUTURE

By F. A. Lart, A. M. I. C. E.

PART I



THE normal movement of time has produced in British railway engineering, as in other branches of national affairs, a more than corresponding development, both detail and general, a survey of which may be of interest, particularly to those financially interested in the vast railway systems of this country.

To professional engineers at least the remarkable developments in British railway practice of recent years does not altogether commend itself; there is about it a suspicion that mere haste has exceeded actual speed, owing to a somewhat inconsiderate development of certain detail matters without sufficient reference to their inter-relations or their general bearing in reference to the whole subject. With this, and directly resulting from it, are signs of at least a temporary halt in this progressive movement and of an inclination to consider what has already been achieved, and even to retrace some of the more hasty steps that have led up to the present situation, so as to arrive at firmer ground and a surer foundation for such further endeavour as may appear to be desirable and necessary. This is inevitable, and as it should be.

The ultra-developments of British railway engineering are only symptomatic of that general national "progressiveness" which has been the leading principle of modern times, and has, in equal measure, degenerated into mere luxury and inexcusable extravagance.

The mischievous effects of the over-praised principle of competition are everywhere self-evident, and nowhere more pronounced and unsatisfactory than in British railway working, where the net result is registered only too plainly in increased working costs, decreased profits and seriously reduced capital values.

While such competition may have vitalized and improved the working of the great trunk lines of the country that are, by force of geographical and other circumstances, placed in natural rivalry, and have, therefore, benefited the national life generally, and while such railways may have themselves derived therefrom a greater strength of financial and commercial position than they possessed before, it is quite certain that it has simultaneously developed in each and all of them a consequent weakness, which only the most robust of them can be expected to bear and to survive according to their present constitutions.

It is equally certain that the smaller lines, and those weaker in capital, position and natural resources of population and commerce, would not have been able to meet or to survive the stress of such competition as those more favourably situated have, so far, more or less successfully encountered.

The average and total capital values of the railway systems of Great Britain and Ireland are not only con-

siderably—about 40 per cent. at the present moment—below those of the last decade of the last century, but they are something like 30 per cent. below their original par values; that is to say, whereas the average and total capital values were during the period mentioned well above par, they are now about 30 per cent. below par.

The average working expenses amount to 62 per cent. of the gross receipts, leaving a net profit on the working of the entire railway system of Great Britain and Ireland of 38 per cent. of the gross receipts, which represents interest on the total capital (par) value of about £1,283,000,000 (one thousand two hundred and eighty-three million pounds sterling), £4.64 per cent. per annum.

This very moderate commercial profit irresponsible trade-union socialists desire, and are endeavouring, with some prospect of success, to reduce to vanishing point, their avowed idea being that the railways exist and should be worked for their own exclusive profit. The question of capital does not trouble them; the capital is there and has been provided by the hated upper and monied classes, and is still held by them, though, as has been shown, in greatly reduced value. The capital assets of the railways themselves and their equipment as at present existing are to fall into these people's hands, and being only of a gradually perishing or wearing-out nature, the question of their maintenance and replacement causes them no misgivings. Whenever necessary, "The State" (that is, those who find the money, as distinct from those who call for it and for whose benefit it is spent) will be called upon to provide the necessary cost of improving the socialists' property.

It is this trade-union socialism which constitutes the chief, the growing and the immediate danger to the future prosperity and development of the British railways.

But those hitherto and at present directly responsible, as directors and chief executive officers, for the working of the various railway systems, must be debited with and are very much to blame for the many extravagances which have characterized the detail and general developments of recent years particularly.

The abolition of second-class carriages on many lines and on all the London - Scotland through routes, which came into force some years ago, was a decidedly retrogressive step, though ostensibly a concession to democratic, progressive ideas. It introduced a monetary standard of personal worth and convenience, with accompanying disadvantages that were undeserved and uncalled for, and had certainly been resented, though, of course, without hearing and without avail, by that very numerous class of the British public whose sensibilities and convenience are surely worth consideration even though they are nowadays only to be estimated on the truly democratic principle of pounds, shillings and pence.

Other railway companies have found it expedient and profitable to cater for such passengers and to retain that intermediate system of moderate comfort, combined with moderate cost, which appeals to and so well suits the convenience of those who are both unable to afford the luxury of first-class traveling and undeserving of and unwilling to experience the very real discomforts of third-class traveling and often more than third-rate companionship. That this restriction of class should, except in the railways referred to, apply only to the longest routes and distances of travel, is as absurd as it is illogical. The discomforts of a short local or suburban journey third-class are bearable, but the prolongation and consequent intensification of these on a longer and sometimes all-night and all-day journey are often really distressing and enervating to those compelled to un-

dergo them. It is a relic of that old policy of compulsion which, in making all but first-class carriages too primitive and too uncomfortable to be endured except by those totally unaccustomed to any form of luxury or comfort, endeavoured to force the public into the expensive practice of universal first-class traveling. It is true that most British railways, and the two-class Midland and North-Eastern systems especially, have improved their third-class accommodation and general comfort very considerably. The same cannot be said of many other railways where the accommodation is restricted and inadequate altogether beyond the possibility of any real or sustained comfort on any length of journey.

There are people, of course, who say they travel third-class "because there is no fourth-class"; these have a sense of the fitness of things which it would be foolish to question, but as those railway companies which run second-class carriages find it distinctly to their advantage to make such provision, it is hardly reasonable for other companies either to coerce their passengers in regard to choice of class, according to the length of their purses, or to neglect a source of profit to themselves and of convenience and profit to their customers and the shareholders.

There have been many unremunerative and generally unfortunate instances of railway enterprise in this country, where either the public interest or commercial prospects have not justified the undertaking, or where, possibly, the force of private and unscrupulous interests has brought such projects into existence, to fail thereafter by neglect or mismanagement or automatically through sheer natural abortion.

There are such instances, unfortunately, on record and within the writer's own personal experience. But the days are probably now quite gone by and hardly capable of recurring when the widespread interests of such important commercial and national concerns as statutory British railways can lie at the disposal either of incompetent or dishonest officials or of indifferent and incompetent boards of directors and shareholders.

The amalgamation or working combination between adjacent railways with competitive systems and interests, or the complete capital combination or absorption of competitive or distant railway systems in which the minor company concerned becomes part of and loses its individuality in that of the other and more powerful one, is a question which has been in evidence for a great many years, and has found in recent years particularly some more or less practical and satisfactory solutions.

The general tendency to amalgamation of both great and small commercial undertakings in this country is not an entirely satisfactory feature of the times. In the case of railways, whether independently prosperous or otherwise, such a policy is obviously open to serious objections from many points of view, and is perhaps only justifiable where such combinations take the form of absorption of small lines adjacent to larger and more influential ones with which they may actually be in a position to compete, but are in themselves hardly more than feeders to such trunk lines, and whose independent existence is perhaps somewhat aimless and little more than a connecting link between neighbouring trunk lines. The logical destiny of these is absorption in one or other of such main lines, whose efficiency and commercial utility they increase and complete.

It is undoubtedly a fact that all the existing British and Irish main lines are themselves simply an agglomeration of original, smaller, independent lines formed in the early days of disjointed railway enterprise, and the various light railways constructed in recent years or projected under the act are certainly to be encouraged if their ultimate aim

and destiny is to be understood as absorption sooner or later into some larger trunk line. Such a prospect, assuming, as it must do, eventual if not immediate commercial success, will itself afford sufficient of that very necessary encouragement to the development of really sound and beneficial railway enterprise in this country which is effectively estopped and paralyzed in these days of trades-union restrictions, of illiberal State interference with capitalistic energy and reproductiveness, and of prospective socialistic confiscation expropriation of all private and corporate wealth and achievements.

There is no space here to dwell upon the gross and typically socialistic injustice which forces the statutory railway corporations of this country to provide out of their own unassisted, State-controlled, State and locally thwarted earning powers the actual money for competitive tramway systems instituted by socialistic local and provincial corporations. This is only one—but a glaring and only too typical—instance of the many gross wrongs worked in this country by, and only since the rise to totally unjustifiable power of, "triumphant democracy." For the present, no doubt, "the power of the purse", so grimly evoked by unscrupulous politicians, lies in the hands of the smaller upper classes, and with them still lies the power of instituting, supporting and working those capitalistic schemes on the existence and future development of which the very existence of this (for the moment) "triumphant democracy" absolutely depends.

For shareholders and others, dividends and business and professional profits reduced by, and rates and taxes increased by, trade-unionist, socialist and otherwise temporarily triumphant democrats, may very well be supplemented, balanced and even increased by exercising this legitimate and government-supported power of the purse by the simple expedient of withholding all voluntary subscriptions to railway and other charities created and existing for the sole benefit of this same triumphant democracy, and actually forming what these people consider, not an act of grace or of benevolent charity, but of "ransom" and "duty." It is time, in fact, that some active resistance was made in good earnest by the upper classes to their avowed spoliation and the expropriation of capital by the lower classes. The burthen of democratic rule is too heavy as it is; it has already broken many and dragged them down to its own level, where it has gladly trampled them lower still, and it is increasing every day, according as "liberal" politicians raise the price of the democrat's vote. As matters stand to-day, capitalistic enterprise in railway and all other matters is at an absolute standstill, and will remain so until the present misgovernment of radicals and democrats ceases to be tolerated and to exist.

As regards the development of rolling stock on British railways, it is not so many years ago since the standard type of passenger carriage ran upon six wheels only, being about 35 feet in length, with a "tare" of about 25 tons; and while many of these remain in use, the general rule is for all the principal trains to be composed of carriages nearly double that length and often double that weight and running on "bogie" trucks of four and even six wheels placed under each end of the carriage. But the carrying capacity of these larger coaches is not increased in proportion, as about 20 per cent. is lost through unoccupied corridor and lavatory spaces. Something is gained, however, in their steadier and quieter running.

Most of the heavy dining and sleeping cars are now run on six-wheel "bogies," and though these are of the largest possible dimensions consistent with loading-gauge requirements, their actual carrying capacity is a greatly reduced percentage, and their earning capacity also, in direct

proportion, as compared with the older "compartment" coaches. The carrying and earning capacity of a railway coach may be reckoned upon an axle basis, i. e., the number of persons carried per axle; and on this basis of comparison the older six-wheel coaches are very much more economical than those running on eight or twelve wheels, whether of the "corridor" or "compartment" type. So also as regards cost of construction and maintenance and running charges. As the total carrying capacity of a train of modern "corridor" "bogie" coaches is appreciably reduced as compared with the capacity of a train of the older six-wheel "compartment" coaches running on the same number of axles, it follows that trains nowadays have to be very much longer and heavier to carry any required number of passengers and to earn the amount of money represented thereby. That necessitates the running of so many more train-miles and so much reduction in net earnings and dividends. It is questionable whether the facilities now provided for dining in trains counteract the disadvantages of the old-fashioned pauses of some twenty or thirty minutes' duration which, on long-distance journeys, used to take place at such stations as Swindon, Wolverton, Preston and York for the purpose of allowing passengers time for a more or less solid meal, or some relaxation from their temporary confinement.

The extravagant and often pseudo-luxury which the internal fittings and arrangements of latter-day carriages, whether first, second or third-class, represent, is both a sign of the times and an entirely wasteful form of expenditure, and is due to the force of blind competition, especially amongst those lines which afford alternative routes over long distances; and it represents not increased earning capacity and net profits, but increased dead weight and prime maintenance, and haulage costs and reduced dividends on capital involved.

It must be remembered that doubling the size and carrying capacity of a train does not halve or otherwise necessarily reduce the mileage run by that train, as shareholders are sometimes told and fondly imagine. It actually increases, and may even also double, the train mileage as regards the carriages; but it does not increase the engine mileage unless two engines are used, when it is, of course, doubled. All depends on the number of carriages and axles comprising such a train, and the more the carrying capacity of a train is reduced by corridor and other waste spaces so much the more effective space has to be provided by additional coaches running on additional wheels and axles, and exactly so much more engine power is required to haul the train. The provision of locomotive power to deal with these excessively heavy trains has become a problem equally pressing and difficult of solution. There are certain narrow and well-defined restrictions to the development of a locomotive which are not met with at all, or to anything like the same degree, in the case of carriage and wagon rolling stock or any other details of railway equipment.

To haul the heavier trains of to-day, carrying any given number of passengers, at the same speed as in former times, when lighter and more capacious trains were the standard, requires a more than proportionate increase of locomotive power, and this has to be obtained by a still more disproportionate increase of size, complexity and dead weight with, unfortunately, a logical and corresponding increase of prime maintenance and running costs, and decreased earning capacity. There is a certain objection to the double-engining of trains which is, perhaps, more theoretical than real, and it is questionable, if such excessively heavy trains have to be run, whether it is not more economical to run them with two engines of moderate size and weight and simple design, such as used to

be the standard type up to a few years ago, but having on that account and generally a much higher margin of net power and efficiency (the terms are synonymous) than the excessively heavy and complicated engines that have been so freely built in recent years for the express purpose of running them. Fortunately, the principle of "compounding," or double utilization of the boiler steam, offers a means of concentrating a maximum of power in an engine of moderate size and weight, as has been already amply proved on the London & North-Western Railway, and only awaits general adoption when a somewhat unreasoning prejudice shall cease to oppose it.

Ten years ago the heaviest and most powerful express passenger engines barely exceeded 50 tons weight in working order, the tender being about half or two-thirds that weight, fully loaded with coal and water, or 75 to 80 tons in all. The heaviest goods engines and tenders were usually only about two-thirds or three-quarters of these respective weights. Nowadays, an express passenger locomotive weighs anything between 60 and 75 tons, with tenders from 30 to 45 tons, in working order, so that an engine and tender complete often exceeds 100 tons dead weight, all of which has to be kept moving before any power is available for the train itself, and is earning no profit. Further, the increased horse-power, gross and net, developed by these engines requires a more than proportionate expenditure of water and fuel; and the contract cost of coal, as supplied to the railway companies and delivered into even their own trucks and on their own rails, is at the present time some 50 per cent. higher than it was, in the writer's knowledge, ten years ago.

It can easily be seen that in any excessively large, heavy and complicated engine a very considerable proportion of engine power is absorbed in moving the engine itself, with a correspondingly small margin of net or "brake"-horse-power available for running the train. And as the main-line express trains of to-day are, as has been pointed out, themselves excessively heavy, it is easy to see how expensive and actually wasteful these modern developments of British railway working are. The writer has pointed this out, in calculated figures, in recent articles in "the engineering" papers and elsewhere.

Finally, the increased weight of both trains and engines makes it increasingly difficult to retain the high actual and average speeds both of earlier years and present day time tables. Even now the actual and average running speeds of the old Great Western broad-gauge trains is barely exceeded and often barely reached in main-line work. Increase of speed represents a much more than proportionate increase of power, and as there are clear and definite limits to obtaining this in locomotives, it would seem as if the end of railway development in these points were very nearly attained.

There comes in also the question of permanent way itself, which has to be strengthened in every detail to meet the strain caused by these increased rolling weights of carriages and locomotives. This has in many railways already involved, and in others will sooner or later require, complete reconstruction of bridges, which is, of course, a most expensive item, and also the provision of heavier and stronger rails and chairs and more numerous sleepers.

The introduction of automatic and highly specialized systems of pneumatic, electrical and hydraulic signaling, with a view to lessening the possibilities and dangers of mistakes on the part of the men in charge of this important detail of railway work, and of eliminating, as far as possible, the human factor in respect of excessive pay strikes and other advantages, seems to have altogether proved either a practical failure or only a partial and expensive success.

THE ADVANTAGES OF PRODUCER GAS-FIRING

By Dr. Oskar Nagel

DURING the past ten years great strides have been made in the application of producer gas for fuel purposes, and it has been found that the use of this gas, in place of direct firing with coal, presents the following advantages:

1. While with direct firing it is impossible to get a complete combustion, this result can be easily obtained by the use of producer gas.

2. Even with the lowest grades of bituminous fuels a practically smokeless combustion is obtained by transforming such fuels into producer gas.

3. With gas firing the temperature is easily regulated and kept constant.

4. With producer gas-firing the waste heat of the products of combustion can be utilized for preheating the combustion air or the gas, whereby a considerable saving in fuel is effected.

5. With producer gas-firing a slight excess of either air or gas can be used, if so desired, for obtaining an oxidizing or reducing flame, which is of special importance to the chemical industries.

6. With producer gas-firing the material to be heated does not come in contact with the solid fuel or ashes. Thence, for instance, in using gas in a limekiln, a purer product will be obtained than with direct firing. In using producer gas under a boiler the life of the latter will be prolonged on account of the purity and uniformity of the flame.

7. Less skill is required for taking care of a gas-fired installation than of a direct fire.

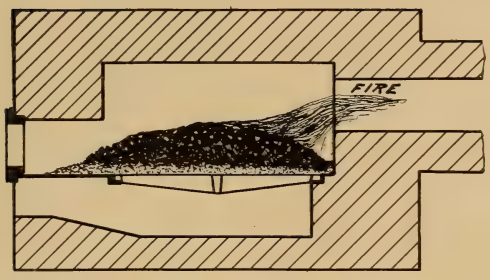
8. Producer gas-firing is especially adapted for central stations, as the gas produced in one producer, or in a battery of producers, can be distributed through pipes to a large number of furnaces.

The advantage of gas-firing over direct firing is obvious, and can be easily understood from Figs. 1 and 2. Fig. 1 shows an ordinary direct fireplace for coal, to which the fuel is charged through a side door. The latter fact makes it difficult to keep up a fuel bed of uniform thickness all over the grate. Fig. 2 shows a gas producer into which the coal is fed from the top by gravity, which is undoubtedly a more rational and convenient way, whereby, at the same time, a fuel bed of uniform thickness can be maintained without difficulty.

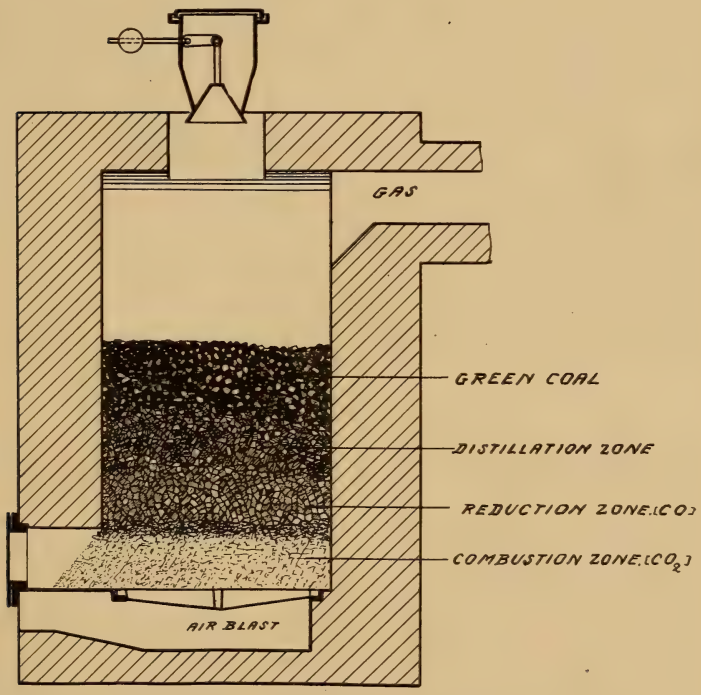
A comparison of these two illustrations further shows that there is nothing complicated in a gas producer, and that it can be defined as a grate fire carrying a fuel bed of considerable thickness—say of 3 feet. It does not matter whether the grate is formed by bars or ashes. (Producer gas manufacture has nothing at all to do with, and is in no way similar to, the complicated process of making illuminating gas.)

The manufacture of producer gas consists mainly in drawing, by means of natural draught or a fan, or by blowing by means of a blower, air through a fuel bed of certain thickness. The entering air combines with the carbon of the bottom layer to carbon dioxide (carbonic acid), which is a non-combustible gaseous product of complete combustion identical with the gas escaping from our chimneys. This gas, by going through the upper layers of the fuel bed, forms a chemical combination with

DIRECT FIRING



GENERATOR GAS FIRING



FIGS. 1 AND 2.—COMPARISON BETWEEN DIRECT FIRING AND PRODUCER-GAS FIRING

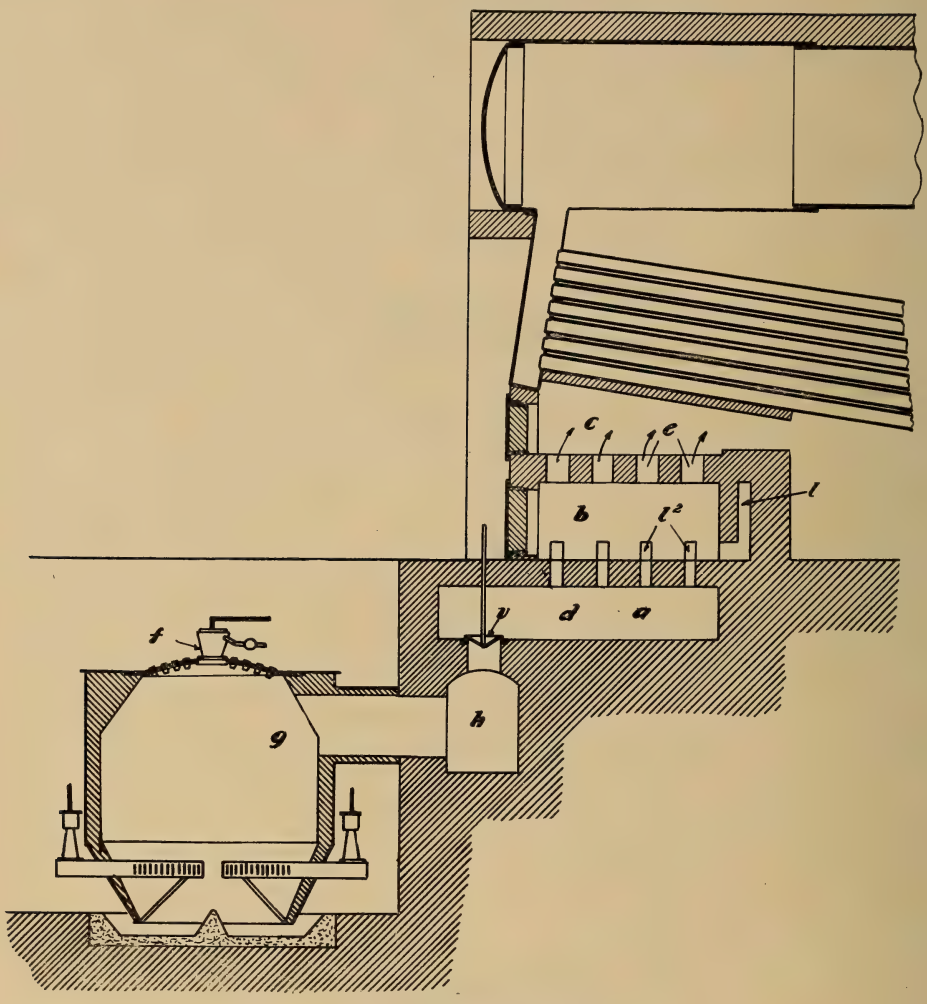


FIG. 3.—GAS-FIRING PLANT FOR WATER-TUBE BOILER

the carbon of these layers and is reduced thereby, the result being the formation of carbon monoxide, which is a combustible gas, and is called producer gas. On account of the air blown through the fuel this gas necessarily contains a certain amount of nitrogen.

The gas producer shown in Fig. 2 is a rather old design; the producers in use at present show many improved features, hence higher efficiency. It has been found that by blowing, in place of air, a mixture of steam and air through the fuel bed, a gas of much higher thermal value is obtained. It has also been found that the attendance necessary for running the producer is considerably reduced if, instead of supporting the fuel bed upon a grate, a so-called water seal is used, the fuel bed being supported by its ash. A modern producer is shown in Fig. 3, in connection with a steam boiler. The steam jet blowers attached to this producer, which is connected to a boiler firing, convey the necessary amount of steam and air to the fuel bed. Once a day such a quantity of ash is removed from the water seal that the fuel bed drops down to

a certain number of inches. The tuyeres through which the mixture of steam and air is passing are so arranged that they effect a uniform distribution of steam and air throughout the producer and thereby a high utilization of the fuel. Below will be illustrated and described a producer gas-fired boiler installation, a gas-fired limekiln, and a gas-fired reverberatory furnace.

Fig. 3 shows a boiler installation provided with gas producer firing. It is easily understood that a battery of boilers can be heated by a battery of producers, and that the boilers can be at an distance from the producers. In the plant shown in the illustration the producer gas goes at first to the gas sewer *h*, which is connected by valves *v* with the gas distributing channels *a*, one of the latter being arranged below every combustion chamber *b*. Thence by closing a valve any boiler can be disconnected from the firing and the quantity of gas to be admitted to the boiler be regulated. Above the channels combustion chambers *b* are provided, into which the gas enters by a number of openings or tuyeres *d* from the channels *a*. In the combustion chambers *b* the gas is mixed with the air required for combustion. The latter enters through channels l^1 l^1, goes through channels in the side walls of the combustion chamber downward to the openings l^2 l^2, through which it enters at both sides of the tuyeres *d* and is burned. Above the chambers *b* there are arranged chambers *c*, which are separated by an arch from the boiler tubes. Thence the fire gases—before touching the tubes—have to pass two chambers, first the combustion chamber proper and then the upper combustion chamber, whereby a complete combustion of the gas is obtained. The arrangement of the channels *l* prevent a loss of heat by radiation.

Coal is charged into the producer every half hour, which is a simple operation; in fact, unskilled labourers are used everywhere for attending to producers, which means also a saving compared to direct firings, where skilled firemen have to be employed. Further advantages are the possibility of using low-grade fuel without interfering with smokeless combustion.

An installation of a producer gas-fired limekiln is shown in Fig. 4. The gas generated in the producer *e* goes through sewer *f* to the gas distributing flue *g*, from which the gas passes through vertical channels to the gas inlet openings *i*. Being under pressure, the gas is equally distributed over the entire area. The combustion air enters at *d*, absorbs the heat stored in the lower part of the shaft and is highly preheated, while the burned material in the furnace is cooled at the same time. The air arrives (on account of the high temperature) at the place of combustion at a certain pressure, which prevents the drawing in of excess air and effects the uniform distribution of the air, as well as of the gas. The combustion of the producer gas by the hot air is taking place between and above the gas inlets. That part of the producer gas which rises upward immediately at the inlet openings does not meet the amount of air necessary for combustion, which, however, is introduced above the gas inlet through the air inlets *o*. This "second" combustion air enters the shaft at *l*, rises through *m*, is distributed in the channels *m n* behind the fire-brick lining of the combustion zone proper, and finally enters the shaft through openings *o*. By means of this arrangement the fire-brick lining is air-cooled from the outside and the rising producer gas completely burned by the second combustion air.

It is evident that, with such a producer gas installation a uniform heat is obtained, that the utilization of the heat is far superior to direct fire, and that a great saving in the fuel consumption (25 to 50 per cent.) is effected. Further advantages are the

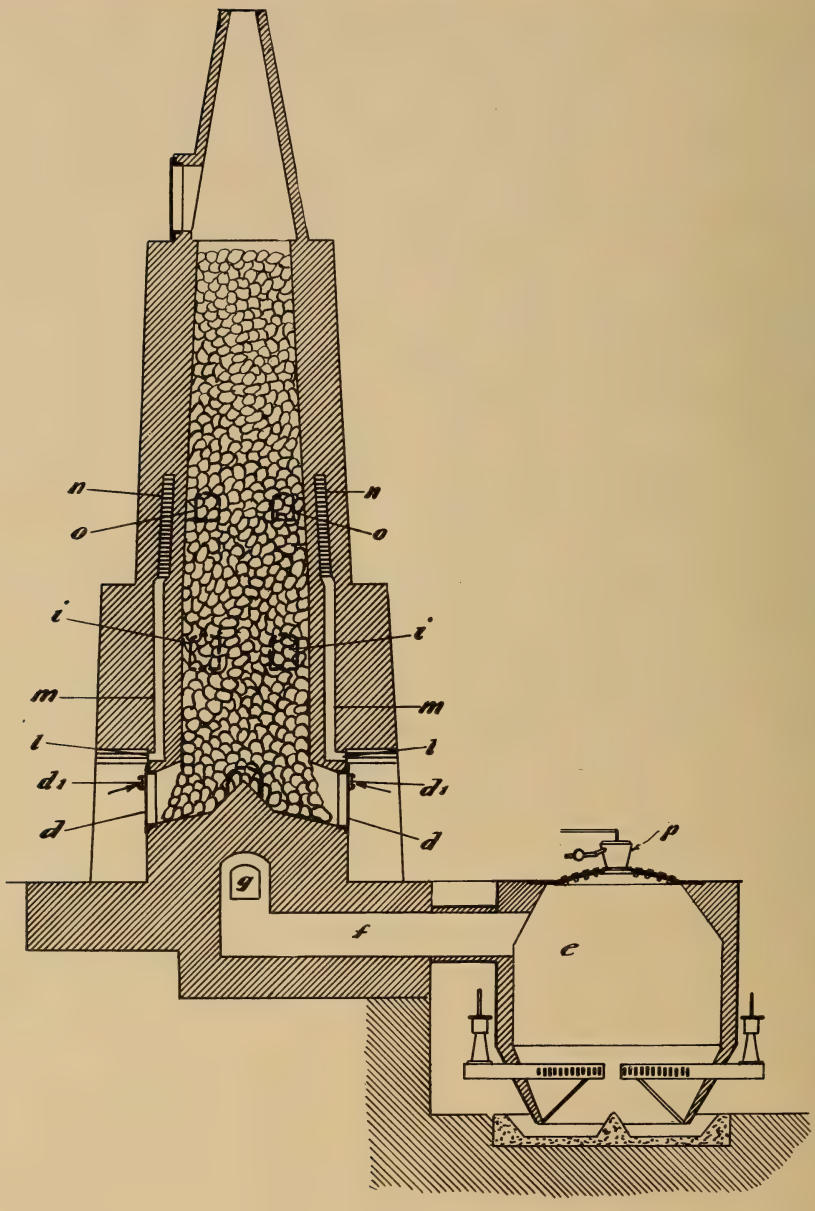


FIG. 4.—LIME KILN ARRANGED FOR GAS-FIRING

production of pure material and longer life of the shaft.

Reverberatory furnaces are widely used in the industries for melting, glowing, roasting and various chemical and metallurgical operations. Most of these furnaces, however, are at present still heated by direct firing, causing a great waste of fuel.

By providing such a furnace with producer gas-firing, as shown in Fig. 5, a saving of 30 per cent. of the fuel is effected. The change from direct fire to gas fire consists mainly in the addition of the gas producer and recuperator between furnace and chimney. The recuperator consists mainly of a system of fire-clay pipes e_1, which con-

nect the flue *b* with the chimney *E*. This pipe system is built into a wider channel *L*, in which the air required for the combustion of the producer gas is introduced at *l*. The air goes in channel *L* around the pipe system, as shown in the cut by arrows, absorbs the heat of the escaping fire gases and carries this heat back to the furnace through the channels and openings *i*. These channels are connected with the hot air chamber *L* of the recuperator by air slits or air channels l_1. In these air slits, which are arranged throughout the width of the furnace arch, the air is brought to a still higher temperature. Thence

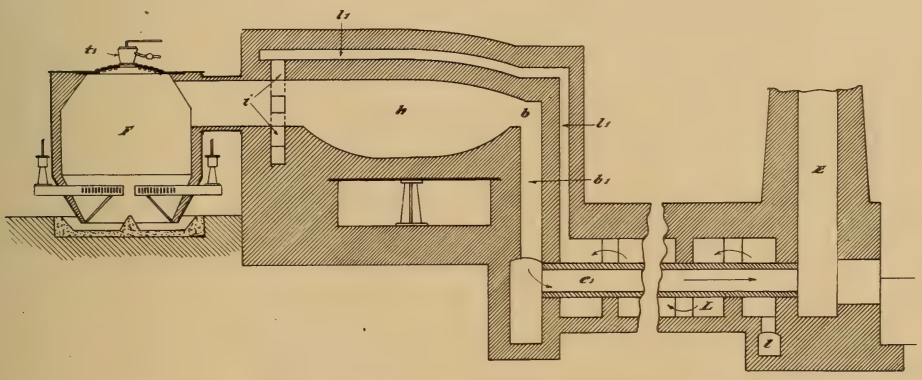


FIG. 5.—METALLURGICAL FURNACE FIRED WITH PRODUCER GAS

at the fire bridge incandescent producer gas is mixed with incandescent air, causing a perfect combustion. In working with a reducing flame the combustion is nearly smokeless. It gets perfectly smokeless by the use of a slight excess of air.

The saving is effected by the higher temperature obtained, by the recovery of the heat in the recuperator, by reducing the radiation of the fireplace, by the exact regulability of the firing, and by the perfect combustion. The life of the fire-brick work is considerably prolonged.

In installations where a temperature of 2,000 degrees F.—3,000 degrees F. is required, the gas and air have to be highly pre-heated before they are allowed to combine. This is effected by leading both the gas and the air through highly heated fire-brick checker work contained in a chamber. There are generally provided two chambers for heating the air and two for heating the gas. While one of each chambers is used for heating, the other is heated by the waste heat of the products of combustion. So-called reversing valves are used for alternately connecting the chambers with the gas and air supply pipe.

Producer gas-firing can be conveniently used in brick kilns, and generally a direct-fired kiln can be transformed to gas-firing at moderate cost.

The main advantage of the gas-fire for this purpose is the fact that the heat of the burned material can be utilized for preheating the combustion air. Furthermore, low-grade fuel can be used even if high temperatures are to be obtained or high-grade goods are to be burned.

With gas-firing the material to be burned does not come in contact with ash, flue dust, etc.; hence fine goods, which previously had to be burned in muffle furnaces, can be burned directly with gas. While with direct firing a number of fireplaces have to be operated, a saving in labour is effected with gas-firing by the fact that only one producer plant has to be taken care of.

With gas-firing an excess of air in the kiln or the admission of cold air is easily controlled and avoided.

It is evident that with only slight

changes a coal-fired kiln can be adapted to gas-firing. In place of the heating shafts (flues) vertical pipes (burners), closed on top, which are provided with rows of numerous gas-outlet openings or slits, have to be installed. These burners are connected by connecting flues or channels arranged in the sole of the kiln and by a main gas flue going all around the kiln.

Below every firing hole there are built in vertically fire-brick tubes *R*, closed on top, which end with their open bottoms into the cross flues *Q*. By opening valve *V*, these flues can be connected with the main flue *K*, so that whenever the valve is opened the gas will go to the connecting flue *Q*, and from there, through the burner *R*, into the burning kiln proper. The products of combustion are led through the flues *F* into the common flue *R*.

Through the flue *S* on top of the kiln hot air from a burnt-out chamber is conducted to a chamber charged with fresh material.

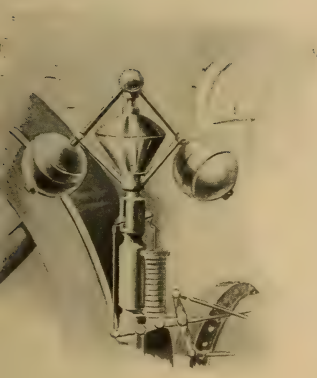
As is seen from the above description, the air only is preheated in this case, while the gas goes to the kiln without preheating. This necessitates the use of a fairly good grade of coal, while by preheating the gas also low-grade coal and even lignite, peat or wood can be used without difficulty for burning the most refractory materials. In Europe the system of "regeneration" (preheating gas and air in chambers filled with fire-brick checker work, which are heated by the products of combustion) is widely used, and in one fire-brick factory a saving in fuel of 40 per cent. and in time of 50 per cent. has been effected.

For the burning of goods which shall not come in contact with the fire gases, especially for burning fine enamels, muffle furnaces are used. In the heating of the latter producer gas presents many advantages as compared to direct firing. The waste heat of the products of combustion is lost with coal-firing, while with gas-firing it is used for preheating the combustion air. With gas-firing the heat radiated by the furnace can be considerably reduced by arranging air slits behind the fire-brick lining and leading the combustion air through same for the purpose of preheating.

The manufacture of cement affords the occasion of generating high temperatures without complicated preheating apparatus, as in this kind of work the large amount of sensible heat of the incandescent clinker can be successfully used for preheating the air up to 800-810 deg. F. The air (of 800 deg. F.), coming in contact with the hot gas as it leaves the producer, combines with the latter, generating a temperature of 2,070 deg. F,. the same temperature as is obtained by coal dust firing. At this temperature the reaction of the cement formation is starting, generating heat and increasing the temperature to 2,700 deg. F. The advantages of producer gas for cement kilns as compared to coal dust firing are: doing away with the expensive coal-pulverizing plant, cleaner finished product and 25 per cent. saving.

PROGRESS OF EUROPEAN GOVERNORS

By George B. Massey, 2d.



SINCE James Watt first conceived the idea of the conical pendulum being used as a means of governing the speed of a prime mover, many devices have been thought out and applied, with varying success. It is the object of this article to enumerate the principal governors now in use on the continent of Europe in regulating the speed of gas engines.

It has long been recognized there that the centrifugal governor (as opposed to the inertia governor) has advantages which make it most desirable for gas engine work. Therefore, all of the master minds engaged in governor research have confined themselves to the centrifugal type alone, with the result that almost all of the governors now in use, and all of those commented upon in this article, are of this type.

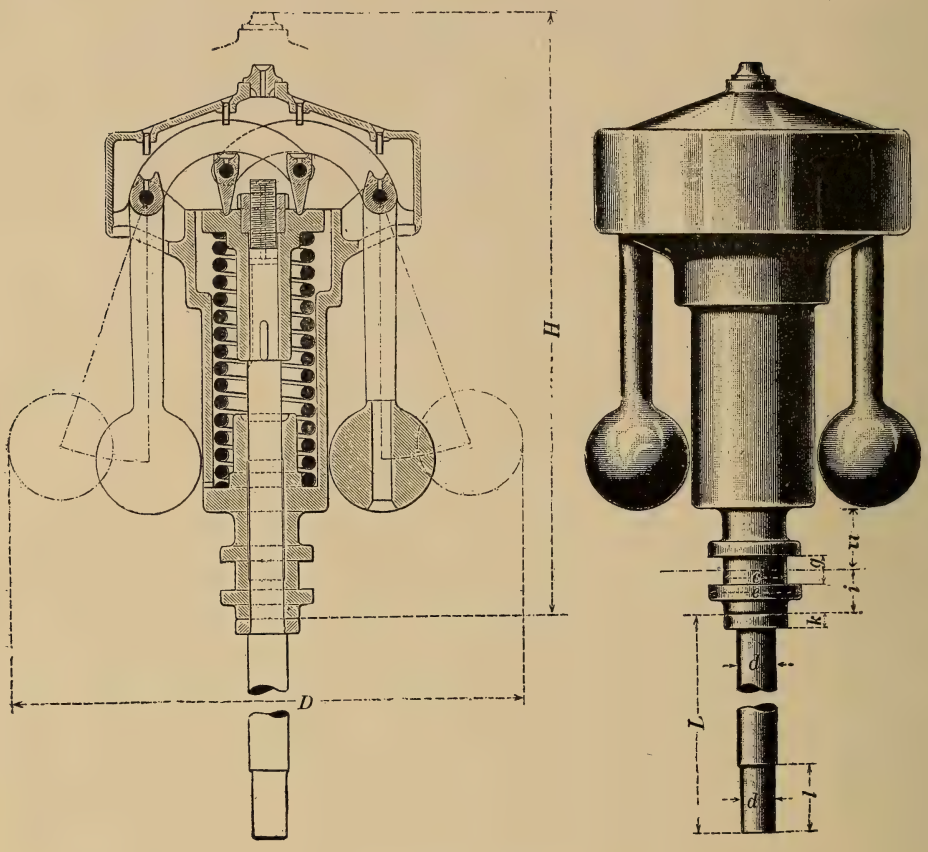
The first governor consisted of two balls, each at the end of an arm, which was jointed to the top end of the governor shaft. As the shaft revolved, the balls would be acted upon by centrifugal force and would tend to fly outward. The valve operating mechanism was so attached to the arms as to assume a certain position for each position assumed by the balls. This was all right for low speeds, as the arc moved through by the balls, when assuming a new position corresponding to a change of speed, was sufficient to give a sensible movement to the valve. At high speeds, however, the balls would fly out so that the arms were almost horizontal, and thereafter any change of speed would cause such a slight change of position of the balls as to be impracticable for moving a valve.

It was soon seen that the balls would have to be held in equilibrium by some force, so that they would normally occupy such a position that the arms would form an angle of about 45 degrees with the axis of rotation. This would allow of considerable motion either way, and would give sufficient movement to the valve. The first method of bringing this about was by hanging a heavy weight on the sliding sleeve of the governor, which weight resisted the centrifugal force of the balls.

Owing to the large mass of this central weight and the time necessary to effect its movement, the advocates of the inertia type of governor conceived that a quicker action would be obtained by relying upon the inertia of a rapidly revolving mass, rather than upon the centrifugal force of a mass whose rapidity of motion was so retarded by the loading weight then considered necessary.

However, the objections to loading were finally removed by the substitution, for the central weight, of a cylindrical helical spring. The spring had comparatively no mass, and responded instantly to any change in equilibrium between its own tension or compression and the centrifugal force of the revolving balls.

The governors representing this period in the development of sensitive



THE TRENCK GOVERNOR

high-speed governors are known as the "Trenck" and the "Beyers." As shown in the cuts, it can easily be seen that the latter is practically the same as the former, except that it provides for a change in the length of the spring by screwing down the large nut at the top, so that it will occupy a position a turn or two lower down in the spring, thereby reducing the number of turns in use. These governors came into use in 1893.

Now the centrifugal force of the balls or revolving weights of a governor cannot all be used in moving valve mechanism, as some of it is nullified in effect by the internal friction of the governor itself. It has been the effort, therefore, to reduce this friction to the minimum in order to obtain the greatest possible percentage of useful governing force. By referring to the Trenck and Beyers governors, it may be seen that the pins or bearings of the levers connecting the balls and the springs are subjected to the centrifugal force of the balls as they transmit this force from the balls to the resisting springs. These pins and bearings give rise to a large amount of friction and have to be very carefully lubricated to prevent this friction from becoming prohibitive. It may be seen that the provisions for oiling are not good, and that oiling can only be done while the governor is at rest.

The Proell governor is built on somewhat different lines from the Trenck and Beyers governors, but the lever joints are still under stress.

In the Hartung governor, which was brought out about this time, this

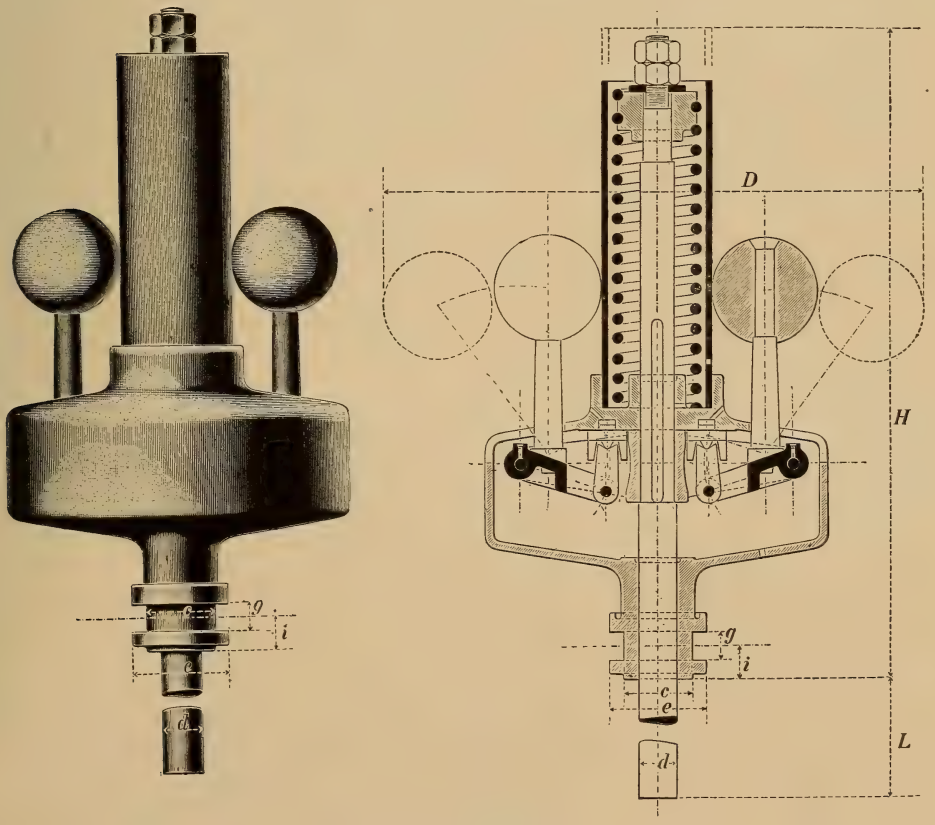
friction was almost entirely avoided by arranging the springs and revolving weights so that they directly opposed each other with no intervening joints. Thus, the levers, or bell cranks, transmitted motion only and no stress, except the resistance which the valve mechanism might oppose to the governor's action. The pressure upon the connections—and, therefore, the friction—was thus rendered exceedingly small.

In 1895 the Tolle governor was brought out, accomplishing not quite so entirely the elimination of friction. One spring in tension supplanted the two springs in compression used by Hartung.

Later designs are those of Heinzmann and the Steinle-Hartung, which differs from the Hartung only in the arrangement of the levers.

The Rost governor is quite different from the foregoing, as it employs spiral springs in place of helical.

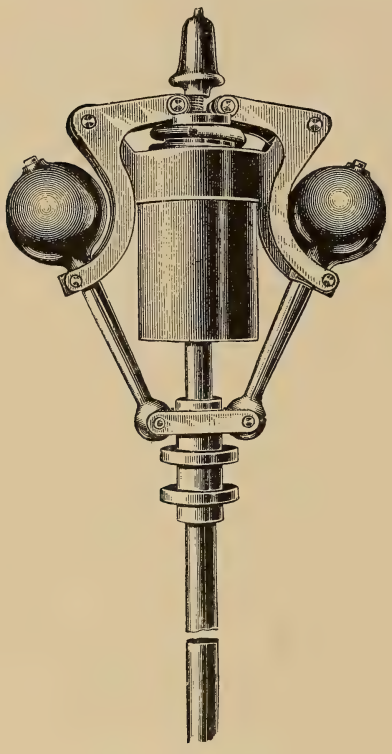
For some time after this no new governors of importance were brought out until the Jahns governor appeared in 1903. It is built somewhat on the lines of the Hartung, with several new and desirable features. The Hartung eliminated part of the internal friction, but it was left to the Jahns to continue the good work by removing from the levers the friction caused by the force of gravity acting on the revolving weights. In place of supporting these weights upon the levers by pin joints, they are each supported by three rolls resting on ways on the lower casing. The weights, therefore, have a truly horizontal path, the upper end of the bell crank lever moving up and down slightly in the



THE BEYERS GOVERNOR

slotted paths provided for it in the weight.

When an engine—and, therefore, its governor—suddenly increases or decreases its speed, the tendency of the revolving masses in the governor is to keep on revolving without any change. If provision were not made for counteracting this tendency, each weight would crowd sidewise against

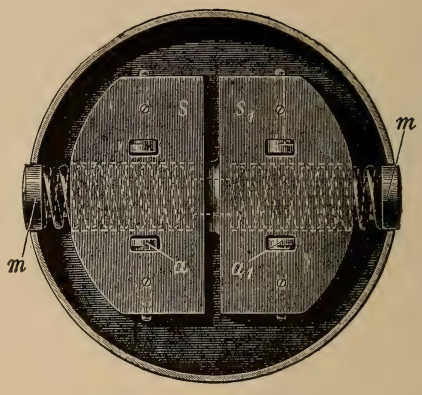


THE PROELL GOVERNOR

its bell crank and the latter against the governor casing at its fulcrum, and this crowding or binding would occur at just the moment when it should not be present, as, at just this instant, the governor is trying to assume a new position to counteract the change in speed of the engine.

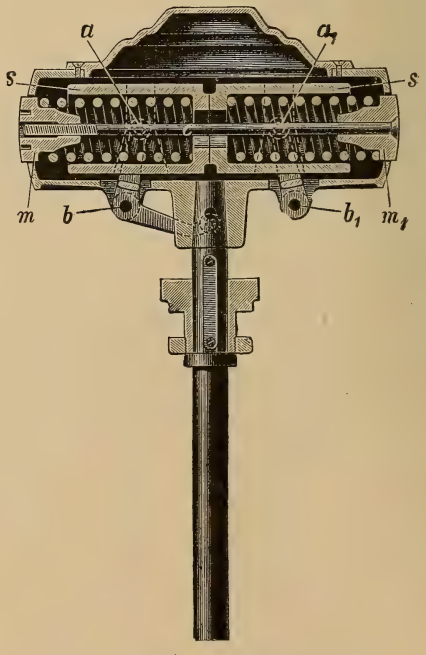
In the design in question, each weight has on its under side two rolls (revolving in a horizontal plane), which engage two vertical ways and prevent any side motion of the weights.

It may be seen from the cuts that

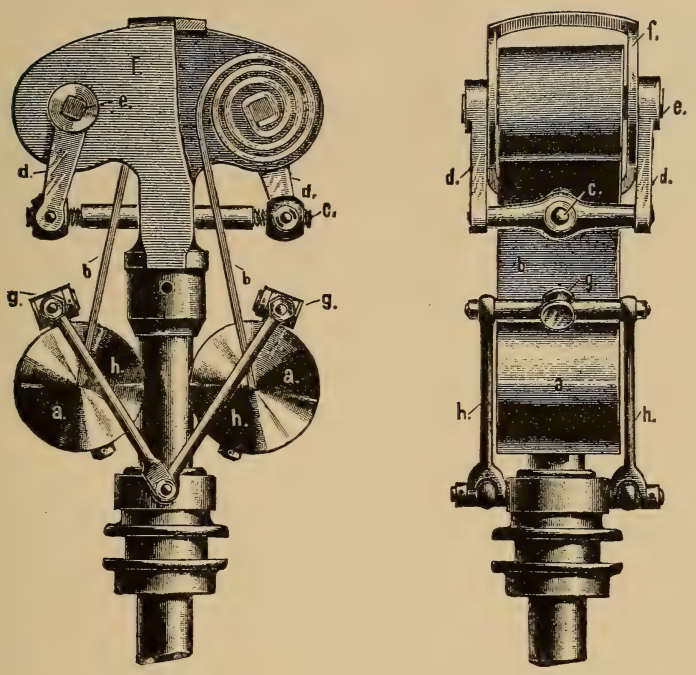


PLAN OF HARTUNG GOVERNOR

more attention is paid to lubrication than formerly. In this last type the casing is oil-tight, and all of the moving parts are in a bath of oil. A very small amount finds its way to the slip collar, or sliding sleeve, below, and lubricates it, the oil in the casing being replenished, while running, at the central oil hole in the top. The feature of the casing being entirely enclosed, prevents dust



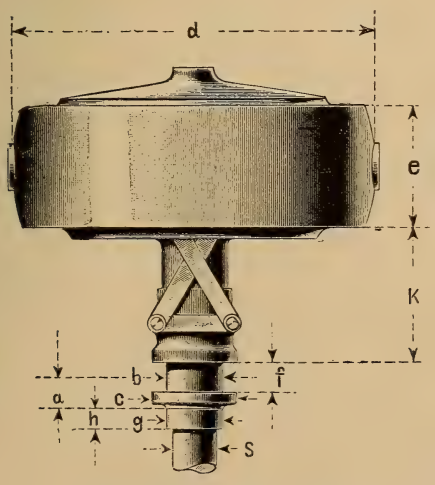
SECTION OF HARTUNG GOVERNOR



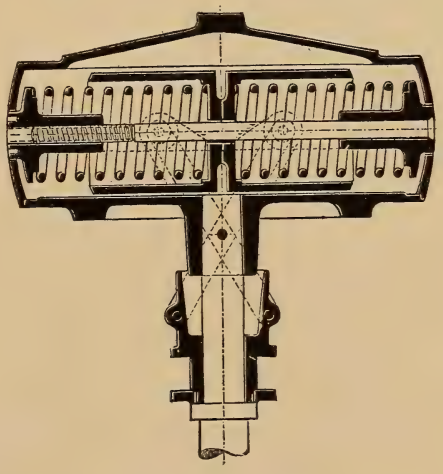
THE ROST GOVERNOR

and dirt from entering, and also makes it impossible for any of the working parts to become rusted if there is any moisture present in the atmosphere of the engine room.

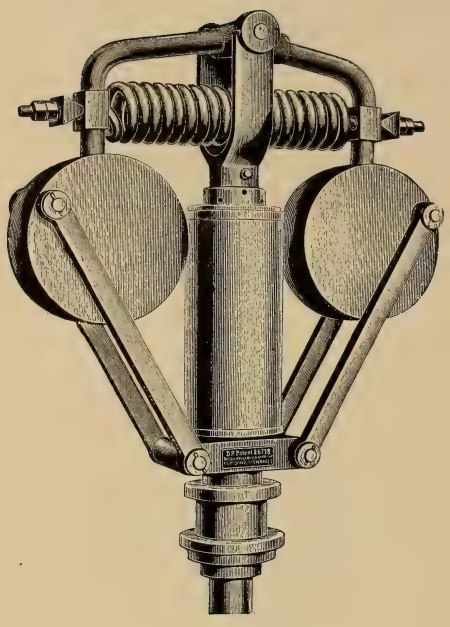
Another evidence of progress since the earlier designs is the fact that the centrifugal force of the revolving weights is so transmitted to the slip collar that the force which can be exerted to move the valve gear is practically constant for any position in the stroke. This is, of course, desirable, as it usually obtains that the



THE STEINLE-HARTUNG GOVERNOR



SECTION OF THE STEINLE-HARTUNG GOVERNOR



THE TOLLE GOVERNOR

valve mechanism offers the same resistance in any position, and so the governing force should be as nearly constant as possible.

Choosing at random from the list of governors named, we find the following:

	Energy.	Regulating Force with 4% Coefficient of Fluctuation.
BEYERS.		
E5, highest position..	323. kg.	12.9 kg.
E3, mid position.....	235.75 "	9.43 "
E1, lowest position...	148.5 "	5.94 "
TRENCK.		
E5, highest position..	235. kg.	9.40 kg.
E4.....	212. "	8.48 "
E3, mid position.....	190. "	7.60 "
E2.....	168. "	6.72 "
E1, lowest position...	146. "	5.84 "
PROELL.		
E5, highest position..	53.5 kg.	2.14 kg.
E4.....	66.5 "	2.66 "
E3, mid position.....	76.0 "	3.04 "
E2.....	83.5 "	3.34 "
E1, lowest position...	93.0 "	3.72 "
JAHNS.		
E5, highest position..	446 80 kg.	17.87 kg.
E4.....	449.26 "	17.97 "
E3, mid position.....	450.55 "	18.02 "
E2.....	451.96 "	18.07 "
E1, lowest position...	456.15 "	18.24 "

There has also been progress in acquiring the desirable property known as "regularity," which means that the differences in speed between any two equal intermediate positions are alike. Taking the same governors as before:

	Energy.	Fluctuation.
BEYERS.		
N5, highest position..	245. r. p. m.	
		N5–N4 1.5
N4.....	243.5 "	
		N4–N3 4.5
N3, mid position.....	239. "	
		N3–N2 3.8
N2.....	235.2 "	
		N2–N1 0.2
N1, lowest position...	235. "	
TRENCK.		
N5, highest position..	177.92 r. p. m.	
		N5–N4 0.35
N4.....	177.57 "	
		N4–N3 0.89
N3, mid position.....	176.68 "	
		N3–N2 1.11
N2.....	175.57 "	
		N2–N1 1.45
N1, lowest position..	174.12 "	
PROELL.		
N5, highest position..	98.2 r. p. m.	
		N5–N4 1.3
N4.....	99.5 "	
		N4–N3 0.3
N3, mid position.....	99.2 "	
		N3–N2 2.0
N2.....	97.2 "	
		N2–N1 3.7
N1, lowest position...	94.1 "	
JAHNS.		
N5, highest position..	276.38 r. p. m.	
		N5–N4 0.56
N4.....	275.82 "	
		N4–N3 0.64
N3, mid position.....	275.18 "	
		N3–N2 0.75
N2.....	274.43 "	
		N2–N1 0.81
N1, lowest position...	273.62 "	

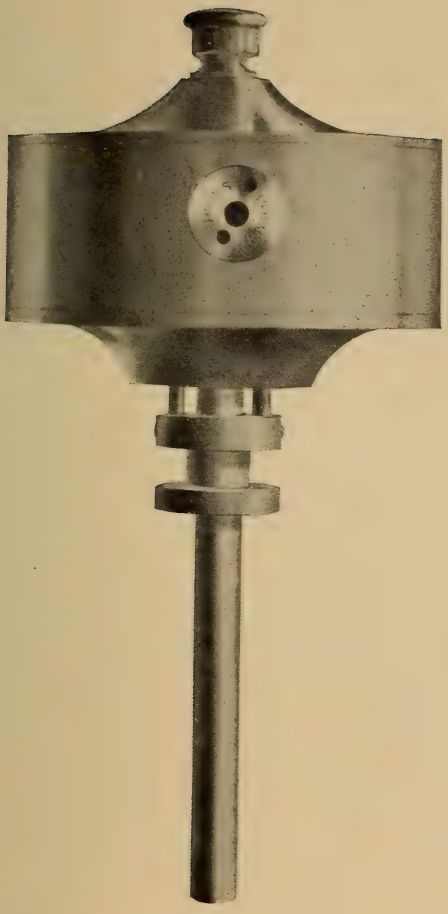
It has been stated above that spring governors act more quickly than do weighted governors. The comparison is usually made by saying that the spring governor will pass from one end of its stroke to the other in the same time that the purely weighted governor takes in passing over only a fraction of its stroke. This fraction of the stroke is called the "reduced sleeve travel" or "reduced stroke" of a governor.

With the reduced stroke of the weighted governor taken as $\frac{1}{1}$ s, we have for the spring governors:

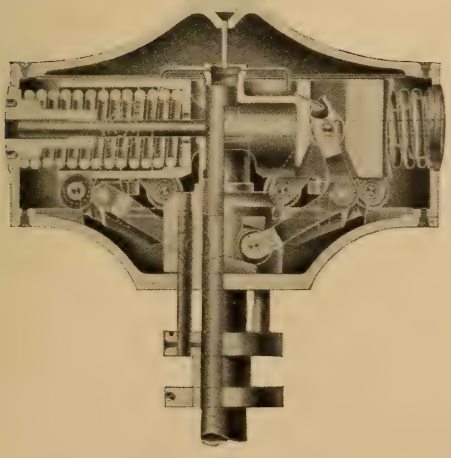
$$\text{Trenck} \quad \frac{1}{2} \text{ s}$$

$$\left.\begin{matrix}\text{Steinle \& Hartung} \\ \text{Beyers}\end{matrix}\right\} \quad \frac{1}{2.85} \text{ s}$$

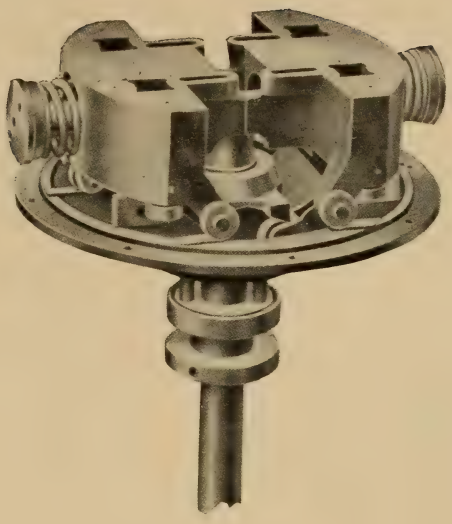
$$\text{Hartung} \quad \frac{1}{9} \text{ s}$$



JAHNS GOVERNOR. EXTERIOR VIEW



SECTION OF JAHNS GOVERNOR



INTERIOR OF JAHNS GOVERNOR

$$\text{Tolle} \quad \frac{1}{13.5} \text{ s}$$

$$\text{Jahns} \quad \frac{1}{15} \text{ s}$$

This means that the latest type in the development of the governor will act fifteen times as quickly as a weighted governor, all the conditions being as nearly alike as possible in both cases.

We note, then, how great the progress has been in the properties which make for close regulation:

Sensitiveness—Quickness of action. Freedom from friction.

Constancy—Same regulating force throughout the stroke.

Regularity—Equal changes in speed produce equal motion at any point of the stroke.

Power has been procured by increasing greatly the number of revolutions.

The governors which are here discussed have been mentioned as adapted to the regulation of gas engines, but they are evidently applicable to steam engines or other prime movers as well.

ELECTRIC SHOCKS

By Henry M. Phillips

SINCE electric wires are to be found overhead, underground, in nearly all buildings devoted to business and in many of our homes, the subject of shocks is of interest to nearly every one. There appear to be very few, however, outside those in the electric business, that appear to have any idea of what constitutes a dangerous shock, where one is likely to be obtained, and what "volts" and "amperes" have to do with it. The accounts seen in the daily papers, aside from the tragedy involved, are, as a rule, rather amusing to one knowing even the rudiments of electricity; all that can be learned from them is that it is safest to keep away from the wires.

The subject of "volts" and "amperes," though not a difficult one, seems to be very little understood; if the writer can throw light on this it will render what follows easily understood. The number of volts measures the force that tends to make a current of electricity flow through a wire, a lamp, a motor, our bodies, the earth, or any other path that may be available. A current may or may not flow as the result of this force, according to circumstances; if the body separating the points at which the voltage is measured is a conductor, a current will flow; if a non-conductor, there will be no current. If we turn off each light in a room by the key in the lamp socket, there will be no current in the wires in that room because the circuit is broken when we turn the key and there is nothing to conduct the current from one wire to the other; the voltage, or pressure, is still there, however, ready to force current through the lamp and cause it to light as soon as we turn the key; it is also ready to give us a shock whether we turn the key or not. The case is very similar to that of water in a pipe; the pressure is there as long as the pipe is connected to the general water system; a current of water may flow or may not, depending upon our opening a faucet or on other means of allowing the water to escape.

When a current of electricity is actually flowing the amperes measure the amount of flow; in the same way that we would say that ten gallons per minute are flowing through a water pipe, we would say that ten amperes are flowing through a wire. We do not say ten amperes per minute, for the ampere measures the rate, not the quantity; if this current continued to flow for an hour the total quantity would be ten ampere-hours. The amperes produce the physical effects ordinarily noted—they cause the filament of the lamp to glow, the motor to revolve, the electro-magnet to exert a pull, and they produce the physical sensation of the shock. The number of amperes flowing in any given case depends upon the pressure in volts that is urging the current on and upon the resistance offered to the flow of current by the path through which it must travel. The question, "How many amperes will a hundred volts give?" cannot be answered unless we know the resistance of the

path; it may be one hundred thousand or it may be one ten-millionth. This may be easily seen by comparing it with the flow of water in a pipe; let us suppose we have a large reservoir of water at 100 pounds pressure. If we allow this to escape through a short length of open pipe 3 feet in diameter, we will have something approaching a flood; make the pipe a mile long and the flow will be considerably diminished; let the pipe be filled with loose boulders that are not allowed to escape and much less water will flow; substitute gravel for the boulders and we will have a moderate flow; sand would make the flow trifling, and clay would cause it to cease altogether. In any of the above cases except the last an increase in the pressure would cause more water to flow; using a pipe of smaller diameter would cause a smaller flow.

Returning to the subject of shocks, it will be remembered that it is the ampere flowing, not in the wire, but through the body, that causes the pain and the injury; the greater number of amperes, the greater the effect. The size of the wire with which we come in contact is of little consequence; any ordinary wire can carry enough amperes to give a fatal shock; the number of volts does not depend upon the size of the wire at all; we can have as much pressure in a small pipe as in a large one. When the current is flowing through our body a great deal of resistance is offered to the flow; it may be compared to a pipe filled with very fine sand, and considerable pressure is required to cause a serious effect; only a slight pressure is needed to force the same amount through the metallic wire, which is like a large, open pipe. To receive a shock it is also necessary that the current flow through the body or a portion of it; that is to say, there must be a path for the current to flow out, as well as in, and the path by which it flows out must lead directly or indirectly back to one of the wires of the same system.

A very heavy current is sometimes used in electrotyping and electroplating establishments. The amount depends upon the size of the plant, and may be as much as several thousand amperes; the voltage used, however, never exceeds fifteen, and may be as low as two or three volts. This low pressure will only be able to send an exceedingly minute quantity of current, measured in thousandths of an ampere, through the body, so although the current may be heating large copper rods so hot that we cannot hold the hand on them, it is exceedingly difficult to get a shock that we can feel at all; it is impossible to get one that is at all serious. This, of course, applies only to the current used for plating. If there are electric lights or motors, they will be operated by a different current, one of higher voltage.

For the next case we will take the wires supplying incandescent lights in a building. To avoid complications, we will first suppose that the current is supplied by a dynamo in the same building. A current, at a pressure of from 105 to 115 volts, is almost universally supplied for operating these lights; in exceptional cases the current may be at 220 volts. We can make sure of this by examining the tag on one of the lamps; it will be marked 110V, or 220V, as the case may be. There is no danger in either case. If one desires, the following experiments may be tried with perfect safety: Stand upon a wooden chair and touch a bare wire or one of the pieces of bare metal carrying current that may be found in one of the cabinets where switches, etc., are located; no shock can be obtained so long as we touch but one wire and are careful not to let any part of our body touch anything else except the chair on which we stand. This is because there is no path by which a current can leave the body; the chair, being of dry wood, acts as an insulator; it may be compared to the pipe filled with clay. At the moment the hand ap-

proaches the metal a tiny spark may possibly be seen to jump to meet it, and at that moment only a faint prick may be felt; it is no more than we can sometimes obtain by rubbing the feet briskly over a rug, and is of the same nature—"static electricity." Now touch lightly with the thumb and finger of one hand two of the wires that form a circuit leading to a line of lights; if the hand is perfectly dry and 110-volt lights are used, it is quite likely that we will feel no shock, especially if the skin is at all calloused; increasing the pressure with which we touch the wires may or may not cause us to feel a slight shock, depending upon the condition of the skin. Dampening the fingers will cause us to feel it in any event if we are touching the right wires. The sensation will not be at all painful, and will be felt only in the hand, as the current simply flows in at one finger and out through the thumb. The resistance to the current is so high that only an exceedingly small amount can flow (the pipe filled with fine sand). A large part of this resistance lies in the skin, which, when dry, may reduce the current to a quantity too small to be felt. As we bear harder on the wire, a larger surface of skin comes in contact with it and allows more current to flow. If 220 volts are used on the system twice as much current will be forced through the fingers as with 110. It is rarely necessary to wet the fingers in order to feel this current, and the sensation may be sufficiently sharp to cause one to draw the hand away quickly. It is not particularly painful, however, and few would hesitate to try it a second time.

Returning to the assumption of 110 volts, we will place one hand on each wire instead of touching the two wires with one hand; again it may be necessary to moisten the fingers in order to feel a shock. The current must now, of course, flow through the length of each arm and through a portion of the body. The tingling sensation may be felt along the arms, but principally in the wrists. It is not unpleasant under ordinary circumstances, though if the hands are moist and we press firmly on the wires it may be a little too strong for comfort. If a piece of metal is held firmly in the hand and brought in contact with the wire the shock will be still stronger, as the current has a better chance to enter the hand. Grasping a large wire firmly in each hand would be decidedly unpleasant, and might contract the muscles so that it would require an effort to let go. There would not be the slightest danger, however. The same experiments may be tried with perfect safety with 220 volts, though it is probable that, after touching the two wires lightly, which may be done without hesitation, the reader will not care to go further. In these cases the subject may fairly be said to have received a shock of 110 or 220 volts, as the case may be. It has been seen, however, that it makes a good deal of difference how we receive the shock. It would be impossible to tell how many amperes were received without using a delicate measuring instrument at the time of taking the shock, but it is certain that only a very small fraction of an ampere has passed through the body. A tenth of an ampere or 100 amperes may have been flowing in the wires when the shock was received; it would make no difference in regard to the shock, as already explained.

The experimenter may next place one hand upon a pipe which forms a part of the general piping system of the building, either gas or water, or if it is a steel building, upon some of the metal work of the building; with the other hand touch first one wire and then a wire upon the opposite side of the circuit. It is extremely probable that no shock will be received; he may, however, receive a shock from one side of the circuit, in which case it will probably be of about the same strength as when he touched two wires, although it may be much weaker. It

is also possible that he will receive a weak shock from both sides of the circuit. This is readily explained. In order to receive a shock at all the current must not only flow through the body to the pipe, but must also flow at some other point from the pipe back to a wire on the opposite side of the circuit; if the wires in the building are properly insulated there will be no chance for the current to return to the wire, consequently no current can flow. It quite frequently happens, however, that a poorly insulated wire comes in contact with a pipe or the metal work of the building; no immediate damage is produced as long as this is the case with one side of the circuit only, but when we touch the pipe and the opposite side of the circuit a shock is received in the same way as when we touch the two wires. Touching the same wire that makes contact with the pipe will, of course, produce no shock. A contact of this kind is called a "ground," and a circuit that is in this condition is said to be "grounded." A wire may have a "weak ground" or a "slight ground" when it is touching woodwork, masonry or the earth. If the point where this occurs is perfectly dry, the result will not be noticeable; if moisture is present, the ground becomes stronger and may, under favourable conditions, be almost as strong as when the wire touches metal. When the weak ground exists a small shock is received, for the resistance of the ground cuts down the current flowing through the body; it is like an additional length of pipe filled with fine sand. A weak ground may exist on both sides of the circuit; in this case a shock is received from both sides. A strong or heavy ground cannot exist on both sides, as the current flowing through from one to the other would quickly cause a breakdown in the system.

Now the chair may be removed and the experimenter stand upon the floor. If the shoes are slightly moist, as is generally the case, the conditions are much the same as before. Standing upon metal or a wet floor a shock may be received from a grounded circuit upon touching one of the wires; the current passes through the entire body, but is felt principally in the arms and legs. No shock will be received on a perfectly dry, non-metallic flooring unless it is very dirty. A piece of clean, dry wood, however thin, will be sufficient to prevent the possibility of a shock. One naturally thinks of rubbers in this connection, but they do not seem to be very satisfactory. No doubt perfectly new and dry ones would answer, but the quality of the rubber is very poor, and under ordinary conditions they seem to have little effect. The shock received when standing on a wet floor is frequently somewhat stronger than that received by touching two wires. This is on account of the excellent contact made by the full surface of the foot with the entire weight of the body upon it.

Although it is perfectly safe to do everything described above, care must be taken to avoid a "short circuit"; this is produced by bringing two wires from different sides of the circuit into actual contact, by forming a circuit between them by metal of any kind—screw-driver, knife or pliers—or by allowing one of the wires of a circuit already grounded to come in contact with pipes or metal work. No shock can be received in this way, but burns may be, the usual result being a blinding flash and the fusing, to a greater or less extent, of the metal parts that form the contact.

It will be seen from the above that when a shock is received through a ground the voltage of the shock is not known; there may be 110 volts on the line, but we cannot say how much of this is taken up by the body and how much by the ground. The same applies to higher voltages. The writer at one time received a shock from a 3,000-volt circuit which, while not altogether pleasant, was by no means serious (it probably

amounted to about 300 volts); under other conditions the full 3,000 might have been received, with fatal results. Similar cases no doubt give rise to the reports sometimes seen of people getting very heavy shocks and surviving.

We will next consider the case where the lighting wires enter the building from the street above ground. There is now a very slight element of danger, although the voltage is the same as before. Wires of dangerous voltage are carried about the streets, and one of these may come in contact with our lighting wires. Fatalities from this cause are, however, extremely rare; a person standing upon a clean, dry wooden or carpeted floor, as is usually the case inside the building, might handle a wire where 2,000 volts or even more are present without getting a dangerous shock through the ground. Higher voltages than this are frequently present in the street, but if they should be thrown upon our house wires they would be almost sure to break down the insulation of the system in such a manner as to cut off the current automatically. It is doubtful if there has been a fatal case from this cause in the entire country during the past year. Houses supplied from overhead wires are likely to use an alternating current; although the voltage is the same, we feel a shock somewhat more severely from the alternating current, 110-volt alternating feeling nearly as strong as 220 volts on the direct current used in isolated plants. Standing upon a dry chair as first directed, one need not hesitate to handle these wires; no shock will be received unless two wires or a wire and pipe are touched at the same time; touching one wire only, no shock can be obtained unless sufficient voltage exists to force current through the chair. This would mean several thousand volts, which would be sufficient to cut the line out automatically, as already stated. Wires entering the building underground may also, through a derangement of the system, carry a dangerously high voltage; there is much less chance of this than with overhead wires, the probability of such a thing occurring being so slight that it may be disregarded. Three wires are frequently found entering the building on an underground system; in this case there is generally 110 volts between the middle wire and either of the outside ones, but there is 220 volts between the two outside wires. The middle wire is frequently grounded intentionally, in which case a 110-volt shock can be obtained between either of the other two and the ground.

Motors are almost invariably operated on either 110, 220 or 500 volts, voltages 5 or 10 per cent. higher being included in the general figures given. What has already been said of 110 and 220-volt circuits applies equally well to motor circuits, except that it is well to avoid touching any part of the motor when the controlling switch is being opened, as at that particular instant a higher voltage may momentarily occur. At 500 volts the current begins to be dangerous; the circuit is nearly always grounded to a greater or less extent, and unless one is careful where he stands a shock is received on touching the wires. This is because the high pressure forces current through obstructions in a greater volume than a low pressure; the pipe filled with fine sand would allow hardly any water to flow at low pressure, but might pass a considerable quantity when the pressure is increased two or fourfold, and a thin layer of clay that would stop all flow at low pressure might be broken away by the higher pressure. Standing upon a clean, dry board one inch thick will prevent any possibility of a shock, so long as we touch but one wire at a time and are careful not to bring the hand or body in contact with any external object that might give the current a path to the ground. Where only a slight ground exists a slight shock may be received in the same

way as with the 110-volt circuit. It is not the voltage that we feel, but the amount of current (amperes) that are forced through the body; one one-hundredth of an ampere passing through the body will give the same sensation from a 500-volt circuit as it does from a 110-volt. The fact that one has received a shock from a 500-volt circuit that did not prove painful is not a sign that the next one will be equally harmless. The following experiments have been tried, involuntarily, by a great number of people: Touch one side of the circuit lightly with the finger while making contact with the other side either through a ground or by actually touching it; the sensation is similar to receiving a violent blow in the chest; a small burn that is deep, but not painful, will be found on the finger where contact was made. Make a better contact, as by touching the circuit with a piece of metal held firmly in the hand, and the blow will be strong enough to knock the experimenter down. It is probable that no burn will result, as the current has a large surface through which to enter the hand; in rare cases the person may become unconscious for a short time. Grasp the wire firmly in the hand, and for a time at least it will be impossible to release it. Serious burns are made where the wire touches the hand, and unless the victim succeeds in wrenching himself free or help is quickly rendered, the result is liable to prove fatal. The last case is of very rare occurrence; it is pretty sure to obtain considerable space in the daily papers when it actually does occur, while in many of the reports seen the victim may exclaim, with Mark Twain, "Accounts of my death greatly exaggerated." On the other hand, people are knocked down by the current every day. It is rather peculiar that the 500-volt shock will, in the majority of cases, kill a horse.

The trolley current is a 500-volt circuit, with the exception of perhaps half a dozen lines recently installed, which go to 1,000 or over; and the statements above apply to the trolley as well as to motors. As the return circuit is through the rails, the circuit is always grounded. It is well to remember, in case of a falling trolley wire, that standing upon a dry board will give full protection, that while sitting in a car there is no danger of shock from a broken wire or other cause if one does not touch metal or wet wood; raising the feet from the floor that may be wet or dirty will do as an additional precaution. If one wishes to remove a wire to avoid shock or for other reasons, it may be done with safety while standing upon a dry, clean board, with a piece of dry board not large enough to stand on, or with several thicknesses of dry paper (a newspaper), or, in case of emergency, a bundle of dry clothing. As it is difficult to get the latter perfectly dry, a shock may be received when this is attempted, but the resistance will be so high that the shock will not be a very severe one.

The deadly third rail also operates at 500 volts, and is no more deadly than has been already shown, except for the probability of a person who is thrown down by the shock of falling across the rail and becoming unconscious. This, of course, is as serious a case even as that of the man who is unable to let go of the wire.

Wires used for street lighting may always be regarded with suspicion; they are exceedingly likely to carry a current of 2,000 volts or more. This will, in most cases, give a fatal current, and the pressure is so great that the precautions previously described are not to be depended upon. One would be reasonably safe, however, if standing upon a chair or stool with perfectly dry wooden legs. As wires of 2,000 volts or more are quite common in the streets, there are many chances for other wires to come in contact with them and so receive a dangerous current. It is, therefore, unwise for an inexperienced person

to touch any outdoor wire, however harmless it may appear.

Lines for transmitting power across country operate on voltages all the way up to 60,000. Precautions are taken with such wires, however, that render it almost impossible for other wires to come in contact with them. A special warning is usually marked on the poles. Lines of 10,000 volts or over may also be distinguished by the fact that large clay or porcelain insulators are used in place of the glass ones generally seen.

Persons rendered unconscious by a shock may frequently be revived by inducing artificial respiration, in the same manner frequently described for reviving persons apparently drowned, the measures adopted for removing water from the lungs and passages, of course, being omitted.

AMMONIA IN REFRIGERATION

By Joseph H. Hart, Ph.D.

WHILE the ordinary engineer knows that the ammonia refrigerating machine is practically the only one in efficient operation to-day, or at least the only one having a long series of successes behind it, he has very little knowledge in regard to the position of ammonia in this field and the reasons for its utilization and development. He knows in a general way that a great many other substances have been tried for refrigerating purposes, and that to-day ammonia occupies a place in refrigeration analogous to that of water in power production; but the reasons for this, if not entirely unknown, are extremely hazy. The fact of the matter to-day is, however, that ammonia is now recognized, theoretically as well as practically, as the most efficient substance for this work, and the reasons for this are well known and the possibility of the discovery of a more suitable substance to take its place in the future is extremely remote.

In addition to ammonia, almost any volatile liquid can be used for refrigeration. Carbon dioxide is used with greater or less success to-day where ammonia is impracticable on account of its odour. This is especially so on shipboard, where an ammonia leak would practically render the ship unhabitable. Otherwise, however, it does not compete with ammonia. Any volatile liquid can be used if it is volatile at ordinary temperatures. Ether, methyl chloride, sulphur dioxide, alcohol, naphthaline, and even gasoline, have been used in this development, but in every case their application has been less efficient than the utilization of ammonia for now recognized theoretical reasons. Theory has been behind practice in this development, and ammonia was long recognized as the most practical substance before it attained its position theoretically as the most desirable, and hence the long list of attempts to use other substances in the hope of obtaining something superior to ammonia.

In order to understand the reason for the particular advantage of ammonia in refrigeration, it is necessary to go over briefly the conditions of its operation and also show its analogy to water in steam engineering. A great deal is said to-day in regard to the use of superheated steam and concerning the utilization of the heat in the steam by adiabatic expansion. The fact of the matter is, however, that if the latent heat of steam had not been available for power purposes to a greater or less extent we would probably to-day be without the steam engine. Water is changed to steam by the addition of heat, and steam occupies a much larger volume than the corresponding amount of water. This increase in volume is the source of power in most steam engines and is represented by the work done before the cutoff. Probably without this change from liquid to gas, with the resulting change in volume, the pressure remaining constant, the steam engine would to-day be in a position analogous to the hot air engine. The same thing holds in refrigeration. It is primarily evaporation of a liquid to a gas and the consequent absorption of the heat of vapourization from surrounding bodies that is the mainstay and

fundamental idea in refrigeration. We have to-day air refrigerating machines which cool by balanced expansion or by making the air do work and cool off. This is analogous to superheated steam adiabatic expansion, and the work obtained by it bears the same relation to the total work, both in steam and refrigerating practice.

Thus we have to consider, in refrigeration, latent heat of vapourization of liquid primarily. Water is undoubtedly the best medium for the conveyance of heat in steam work, because it possesses an extremely large latent heat of vapourization. Very few substances compare with it in heat capacity per unit of mass. Thus, the first requirement of a refrigerating substance in the same way shall be that it must have a large latent heat of vapourization. The rules governing the relation between the latent heats of substances and their various other properties are well known to-day by scientists, but at the time of the development of ammonia in practical refrigeration they were unknown. The latent heat of vapourization of each substance had to be determined experimentally, and nothing was known in regard to the law which determined its value. It can be said offhand to-day, from scientific data, that ammonia is undoubtedly the most efficient substance for refrigeration when all the factors are considered. All the substances ever utilized in refrigerating machines possess high latent heat to a greater or less extent, but ammonia possesses the greatest latent heat of vapourization next to water. All substances known as the permanent gases also possess high latent heats of vapourization and, with the exception of a large number of fairly complex organic compounds, this completes the list.

The question naturally arises why cannot the latent heat of vapourization of water be utilized for refrigeration, since it has the largest known latent heat, and the answer is that it has been used, with more or less success, but that it fails from a consideration of one of the other necessary conditions. The substance must evapourate at a lower temperature than that of surrounding bodies, in order to absorb heat from them, and water in general has a boiling point of a higher temperature than that of surrounding bodies. Hence, under ordinary circumstances refrigeration cannot be produced. The evapouration requires the addition of heat, but the boiling point of the liquid is a function of the pressure at which it takes place. Thus, water under pressure has a higher boiling point than when allowed to boil freely in the open air. This boiling point rises steadily with increase in pressure, and is almost proportional to it. In the same way diminution in pressure lowers the boiling point. In fact, if the pressure of the water vapour immediately over a body of water is sufficiently reduced, it can be made to boil at a temperature approximating that of solidification, or the freezing point of water. Hence if the pressure is diminished sufficiently, the latent heat of vapourization of water can be used at 32 deg. F. for refrigeration, but as fast as boiling occurs new vapour is created, and this tends to increase the pressure unless the vapour is removed. The removal of the vapour necessitates the use of large vacuum pumps, and this is the stumbling block to-day in the utilization of water for refrigeration. In some cases chemical means have been utilized to absorb water vapour in an analogous manner to that in which ammonia vapour is absorbed by water in the absorption machine. Water absorption machines can utilize sulphuric acid, calcium chloride, or any efficient chemical dryer, but the expense is prohibitive and the efficient practical working of the machine is impossible. Sulphuric acid was utilized in a few machines at the beginning of the development of mechanical refrigeration. It was found that its ab-

sorptive power for water deteriorated rapidly, that it must be constantly stirred to present new surfaces for absorption, and that it was extremely detrimental in its action on the containing vessel. However, its cost was the main feature, and this development never attained practical significance. The removal of the water vapour by vacuum pumps is utilized to-day in a few scattered plants. This process freezes the ice very rapidly and makes what is known as white ice in the trade, which is often an uncommercial product, although in reality it is much purer than the clear article.

Thus we come to the further condition that the substances must have a large latent heat and a low boiling point. Water is impracticable on account of this latter condition, and attention was immediately turned to other substances. Very few substances are as common as water, and most of the substances available under these conditions were comparatively rare and required artificial production. Under these circumstances free evapouration and the consequent loss of the material could not be permitted, hence the material had to be recondensed and utilized over and over in a closed cycle. This necessitated, in the ammonia compression machine, the utilization of a compressor and condensing coils for recondensation, or the absorber and the condensing coils in the absorption machine. A cask of ammonia liquid or carbon dioxide, gasoline, ether, or any volatile liquid, by its evapouration in the open air will produce refrigeration very similar in amount to that produced by the machine, but it is then lost and requires to be replaced in some form or other. This is the reason for the machinery required in refrigeration to-day. The reproduction of the refrigerating material is the only problem which must be met.

With the exception of the ammonia absorption machine, chemical methods have failed conclusively, up to date, to perform this reproduction, and the duty falls upon the compressor. The temperature of liquefaction of a volatile gas depends primarily upon its pressure, and in this respect is analogous to that of water vapour and its temperature of vapourization. With increase in pressure the condensing temperature of a volatile gas rises and, if below the critical temperature, it can be condensed by pressure alone. Increase in pressure of the gas requires compression by mechanical means, and it has been found better in practice to increase the pressure of such volatile gas no higher than is necessary to condense by the use of cold water, which is generally available. Thus, if ammonia compression were carried on to a much higher pressure, no condensing coils would be necesary, and the gas could be compressed in the cylinder itself. It would, however, then have to be cooled off from this high temperature to normal temperature or its evapouration would absorb this extra heat only. This explains the action of the compressor and condenser as used to-day. The volatile liquid should not be of such a character that its variation of pressure with temperature is such that it requires a prohibitive pressure for its liquefaction. These are the actual conditions as they exist to-day with all of the substances known as permanent gases. They have high latent heats and low boiling points, but the pressures required to produce condensation at normal temperatures are so great as to render their utilization prohibitive. Carbon dioxide just falls outside of the range of this class of materials. It has a large latent heat, although this is only a fraction of that available in ammonia. It compensates for this, however, in the diminished volume of the liquid. Hence 1 cubic foot of carbon dioxide liquid compares very favourably in refrigerating power with 1 cubic foot of ammonia liquid. Although it has a much smaller latent heat of vapourization per pound of material involved,

the number of pounds in a cubic foot is much greater for carbon dioxide than for ammonia, and the same statement holds in regard to the two vapours. Hence in the compression of the vapour a given cylinder volume contains a much larger quantity of refrigerating material with carbon dioxide than is generally supposed, if compared to the same volume of ammonia vapour. This is further increased by the much higher pressures utilized in a carbon dioxide compressor and the increased capacity which results on this account. However, a carbon dioxide machine, even if all these factors are given consideration, does not compare in any way with ammonia as a refrigerating substance. In order to be condensed at temperatures easily available in practice, it must be compressed to a pressure ranging from 900 to 1,200 pounds. And this not only means a large amount of work required of the engine, but considerable difficulty in constructive details, to stand this pressure continuously.

Thus we see that a refrigerating substance must have a high latent heat, low boiling point and low pressure of condensation at normal temperatures. Ammonia satisfies these three conditions best. Of course, a further condition might be added, that the weight of the substance per unit volume should be large, in order that a medium-size machine can possess a normal capacity. This latter condition militates against the use of air and other permanent gases, but they do not require further consideration on account of the former condition of low condensing pressure at normal temperatures. Ammonia, as has been said, satisfies all these requirements best of any known substance. It boils under normal pressure conditions at a sufficiently low temperature for all practical refrigerating purposes. Forty degrees below zero can be readily obtained by it if necessary, although the efficiency for this temperature is not as great as in the carbon dioxide plant. This, however, is an abnormally low temperature, and if the boiling point of the ammona approaches 0 deg. F. it is satisfactory for most commercial conditions. It can be liquefied by ordinary running water at a pressure of 180 pounds, and its latent heat compares very favourably with that of water, the highest substance known. Further, it has a high specific gravity, and an ordinary compressor possesses fairly large ammonia capacity, although this does not compare with the carbon dioxide machine.

Now in regard to the development or discovery of other substances more suitable than ammonia, the possibility of such occurrence is extremely remote and theoretically almost an impossibility. Latent heats, boiling points and pressures and condensing pressures are related to each other in physical science in a way now known to be exact and definite, although the cause for such relations is unknown. Thus the latent heat of vapourization times the atomic weight, divided by the absolute temperature of boiling, is a constant for all substances, with a close degree of approximation. Now we have limitations on boiling points for this development. They must be somewhat below normal atmospheric conditions. The latent heat must be high. Therefore, in order for this product to be a constant the molecular weight must be small. Now all substances possessing molecular weights which are small have been tried and the conditions for their utilization in this development have been considered, and when all the influencing factors are considered and given their proper weight ammonia has integrated to the largest resultant efficiency. Hence the discovery of a new refrigerating substance superior to ammonia involves the discovery of some entirely new substance known to science today, or the change of conditions which have developed this conclusion.

THE DEVELOPMENT OF TORPEDO CRAFT

IN the last issue of this magazine we published a comprehensive review of the development of torpedo boats and destroyers by Mr. Archibald C. Hurd, this including illustrations of a number of vessels in various navies. We now supplement this paper by illustrations of one of the latest vessels of this kind, one which has made such remarkable speed upon her trial runs as to establish new records, and thus to attract especial attention to the possibilities of this kind of craft. We refer to H. M. S. *Tartar,* one of the new destroyers just completed for the Royal Navy.

The remarkable results attained by the *Tartar* render it a matter of interest at the present time to note the gradual development of speed in these little vessels, and hence illustrations of several notable destroyers of successive periods are here given, showing the development of the speed element in such boats very clearly.

The *Ariete,* built by Messrs. Thornycroft for the Spanish Government, is 148 feet 3 inches long, 14 feet 6 inches beam, and 5 feet draught, and in 1886 this vessel developed a speed of 27 knots, holding the record for that date. This was followed by H. M. S. *Daring,* of slightly larger dimensions, being 185 feet long, 19 feet beam and a draught of 7 feet, with a displacement of 260 tons. The *Daring* was fitted with twin-screw, triple-expansion engines and Thornycroft water-tube boilers, and in 1893 made a speed of 29 knots, being the first vessel to reach that speed.

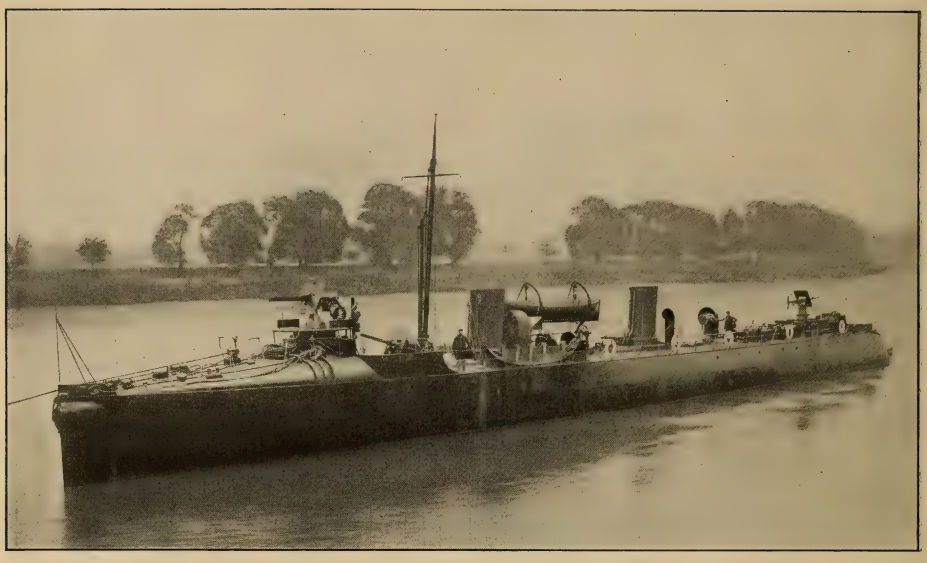
The first boat to attain a speed of 30 knots was H. M. S. *Desperate,* a destroyer again somewhat larger than its predecessors, being 210 feet long, 19 feet 6 inches beam, with a draught of 7 feet 2 inches. This boat made a speed of 30¾ knots in 1896, being, as we have said, the first boat to surpass a speed of 30 knots.

Another interesting vessel shown in the illustrations is H. M. S. *Albatross,* this boat holding the record for speed of any warship from 1899 to 1901. The *Albatross* was still larger than the *Desperate,* being 227 feet 6 inches in length, 21 feet beam and 8½ feet draught, and, with a powering of 7,900 indicated horse-power, made a speed of 32.3 knots.

We come now to the latest product of the Thornycroft Works, the *Tartar,* this being one of the new boats of the 33-knot class, built at the Southampton works of the firm, and shown, just before launching, in the illustrations of the yard, the same photographs showing also on the right the new torpedo boats No. 19 and No. 20, under construction for the British Navy.

The *Tartar* is fitted with turbines of the Parsons type, built by Messrs. Thornycroft, as well as Thornycroft boilers arranged for oil fuel, the length of the boat being 27 feet, beam 26 feet and depth 17 feet 2 inches, with a displacement of 850 tons. The general shape of the boat is that usually adopted by Messrs. Thornycroft, including a graceful turtle deck in place of a raised forecastle, the water thus being thrown overboard. The armament of the *Tartar* consists of three 12-pounders and two torpedo tubes.

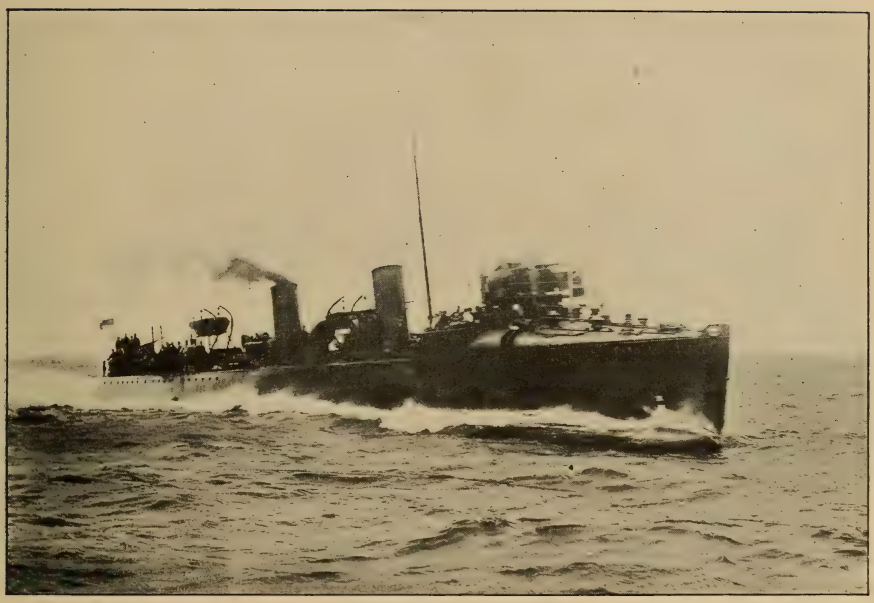
During the preliminary trials the *Tartar* broke the world's record for



H. M. S. DARING. THE FIRST BOAT TO ATTAIN 29 KNOTS, 1893

speed by attaining 35.952 knots on an Admiralty course. The final speed trials were conducted on Monday, December 16, 1907, in the presence of various Admiralty officials. On this occasion the vessel maintained the unprecedented speed of 35.363 knots throughout a continuous run of

SPANISH DESTROYER ARIETE, 27 KNOTS. 1886



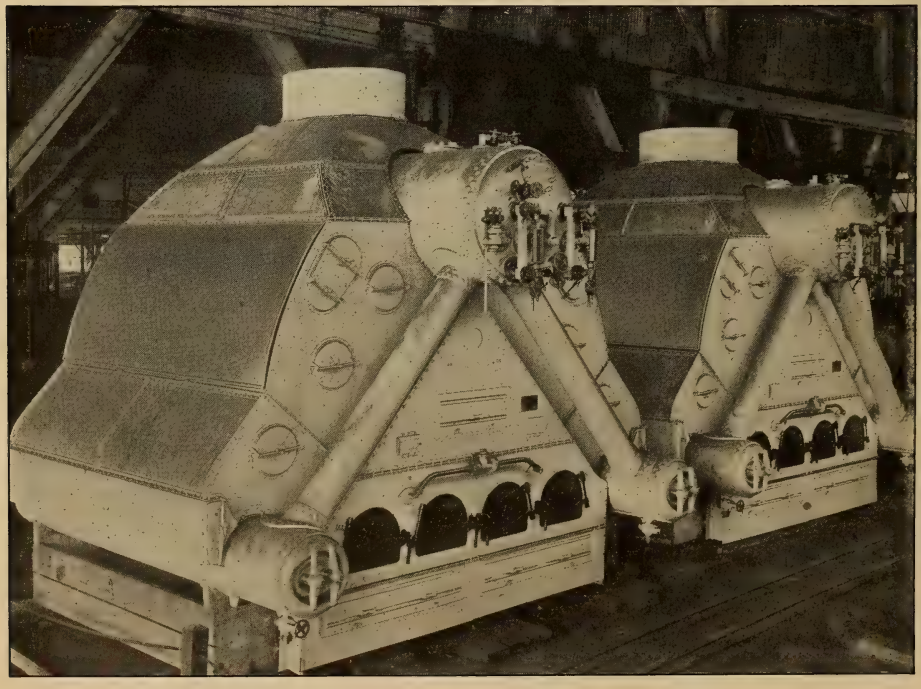
H. M. S. DESPERATE. THE FIRST BOAT TO ATTAIN 30 KNOTS, 1896

H. M. S ALBATROSS BUILT BY JOHN I. THORNYCROFT & CO., LTD. HOLDER OF SPEED RECORD 1899-1901

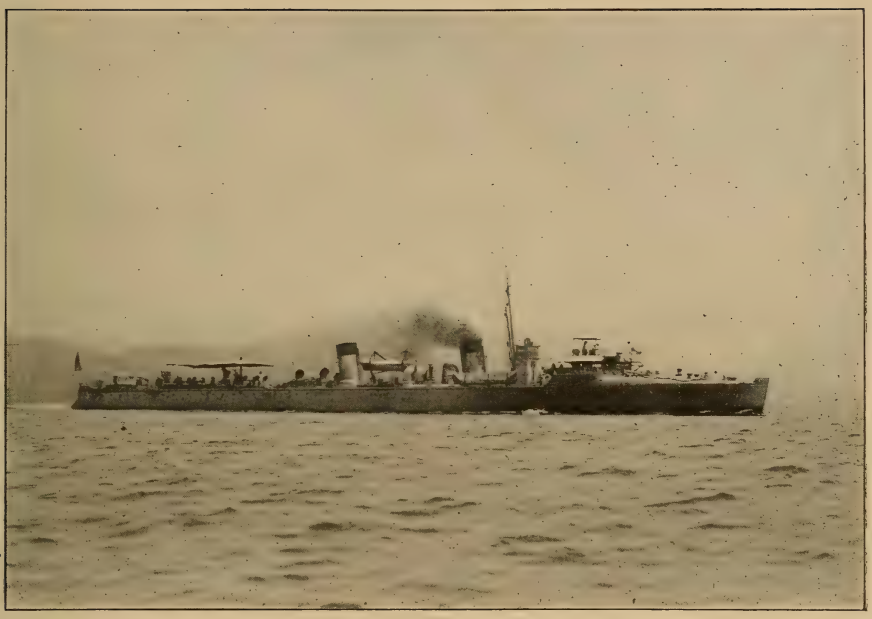
H. M. S. TARTAR. BUILT BY JOHN I. THORNYCROFT & CO., LTD.

six hours' duration, covering a distance during this period of nearly 233 miles.

On six runs over the measured Admiralty mile, during the six hours' run, the main speed proved to be 35.672 knots, while the best speed attained on any one run was 37.037



THORNYCROFT WATER-TUBE BOILERS AS INSTALLED IN TORPEDO-BOAT DESTROYERS



JAPANESE DESTROYER SHIRANUHI, IN SERVICE OFF PORT ARTHUR

THE TARTAR BEFORE LAUNCHING, AT THE THORNYCROFT WORKS, OPPOSITE SOUTHAMPTON DOCKS

knots, thus creating still another record.

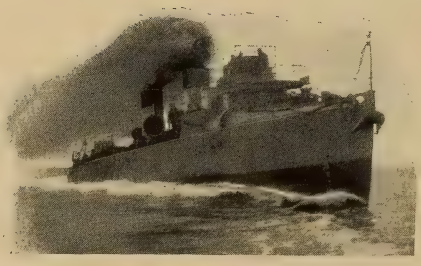
The whole of the machinery worked excellently during the very severe trials, and the boilers maintained an ample steam pressure at all times, the consumption of oil fuel being very considerably within the guaranteed limit.

The following table gives the comparative figures relating to the *Tartar* and such of the other vessels of the 33-knot class already completed:

	Speed On Measured Course	Speed Throughout Six Hours' Run	Speed On Best Run Over Measured Course
Cossak	33.15	33.1	33.65
Ghurka	34.00	33.91	.....
Mohawk	34.51	34.245	35.294
Tartar	35.678	35.363	37.037

In this connection we give also an illustration of another Thornycroft boat, the *Shiranuhi,* of the Japanese Navy, this photograph having been taken off Port Arthur during the Russo-Japanese war. The *Shiranuhi* is 210 feet long, 19 feet 6 inches beam, and 7 feet 2 inches draught, with a displacement of 307 tons. With a powering of 5,800 horse-power upon twin-screw, triple-expansion engines, this boat made a speed of 31 knots, and was highly commended by the Japanese Admiral for useful service during the war.

In view of the long cruise now being made by the torpedo-boat flotilla of the United States Navy, the behaviour of these little craft is certain to attract renewed attention at the present time, and although the large battleship is necessarily the main strength of the modern fleet, the torpedo boat and the destroyer must be considered as most important and valuable auxiliaries, to be maintained at the highest pitch of efficiency and ready for maximum bursts of speed upon immediate demand.



Current Topics

WITH the death of two eminent members of the International Niagara Commission, Lord Kelvin and Dr. Coleman Sellers, there have passed away in Great Britain and America two leaders in the broad field of theory and practice of engineering. It is not intended here to give any extended memorial notice of these famous engineers, since their careers have already been very fully covered in biographical notices in these pages. In the issues for May and June, 1899, the career of Lord Kelvin is very fully covered in a richly illustrated biographical sketch by Mr. J. D. Cormack, while the interesting life of Dr. Sellers has been reviewed in the issue for August, 1903, in what proved to be the last article by the late Dr. Henry Morton.

The varied knowledge and profound learning of Lord Kelvin have formed topics for discussion at many times, and doubtless his great achievements, such as the electrical engineering of the Atlantic cable and the development of Niagara power, will attract the greatest degree of attention from the world at large; but to the engineer the extremely practical side of Lord Kelvin's work must always be of interest. There was probably never such a signal refutation of the statement that theory and practice are opposed than appears in the whole life of William Thomson, from the time he wrote his thesis on the figure of the earth to the time of the invention of the siphon recorder and the non-leaking faucet, not to speak of the array of practical applications developed throughout the whole of his long life.

Dr. Sellers, while a man of wide theoretical attainments, represented, in nearly all of his work, the development of the practical side of science; and, with his keen observation and acute perception of the useful possibilities of phenomena which, to others, seemed merely interesting, was especially equipped for the development of mechanical engineering in the United States. Probably to him, more than to any other one man, the characteristic features which distinguish American machine tools are due, including the transformation from the architectural monstrosities and scroll-saw vagaries which disfigured the early productions of the last century to the symmetrical and scientific designs of to-day.

Both men have left their indelible impress upon the world in which they lived, both gave to the world far more in value than they ever received from it, and both passed away full of years and honours, leaving behind them examples which shall not soon be forgotten.

THE proposition of the Government of China to introduce a uniform system of weights and measures throughout the Empire is attracting attention among the merchants and manufacturers of Europe and America who have extensive trade relations with the Chinese Empire, and both in England and the United States the desirability of securing the adoption by China of the British weights and measures has been perceived. The total volume of trade between England and China last year, including that of Hong Kong, was £19,219,827, and already a petition, signed by more than 200 important firms trading with China, has been presented through the Chinese Minister in Great Britain, urging the adoption of British units by the Chinese Government.

In the United States the matter is also being taken up actively by organizations of manufacturers, and the Secretary of Commerce and Labour at Washington is in touch with American manufacturers whose interests are involved. The American Minister at Peking has also been instructed to follow the question closely, with a view to preventing, if possible, the adoption in China of any system of weights and measures which would interfere with the normal development of American trade interests in that country.

FROM recent returns for the year 1906 ended in March last, the importations of merchandise into India for the year were valued at Rs. 108, 30, 69, 144, as against Rs. 103, 06, 56, 602 in 1905, or an increase of 5 per cent. Among the imports were:

	1905 Rupees	1906 Rupees
Iron and Steel.....	6, 64, 39, 000	7, 55, 80, 000
Machinery and millwork	4, 92, 56, 000	5, 79, 89, 000
Railway material	1, 62, 26, 000	4, 15, 78, 000
Instruments and apparatus	91, 29, 000	1, 19, 87, 000
Building materials.....	45, 99, 140	49, 86, 790
Coal	32, 12, 000	48, 60, 000

Of the total, the United Kingdom supplied 66 4/5 per cent., Germany 5 3/10 per cent., Belgium 4 per cent., United States 2 3/10 per cent, Japan 1⅓ per cent, France 1 2/5 per cent., etc. Metals represent 9¼ per cent of the total value of importations of merchandise, and copper represented 13 4/5 per cent. of the value of metal imports. The price of metals being high during the year, we find a diminution in the quantities imported. Thus, a quantitative decline of 22 per cent., accompanied by an increase of 11 per cent. in total value, the average specific value of India's metal imports having risen by 11¼ per cent.

During 1906 iron imported was valued at Rs. 4, 31, 83, 326 and steel Rs. 3, 23, 96, 882. Iron rose 14 3/5 per cent., i. e., from Rs. 7.3 5/12 to Rs. 8.4⅓ per cwt., while steel advanced 8.4 4/5 per cent., i. e., from Rs. 5.10 5/6 to Rs. 6.2 5/6 per cwt. Bars, sheets and plates, hoop, angle, bolt, rod, beams, pillars, girders, bridge-work, pipes, tubes, etc., totalled in iron 261,095 tons and in steel 262,048 tons, and of the total quantity the United Kingdom supplied 63¾ per cent, as against 54 per cent. in 1905, whilst Germany and Belgium represent about half this amount. Lead declined 28¾ per cent. in quantity, to 102,455 cwts., whilst tin increased 51⅓ per cent. in quantity, 32,011 cwts., about half of which came from the Malay archipelago. The steady increase of machinery is an indication of sound economic development. The various classes of machinery imported into India show:

	1905 Rupees	1906 Rupees
Textile	2, 48, 98, 000	2, 27, 45, 000
Steam engines and parts	1, 00, 33, 000	1, 31, 13, 000
Electrical	23, 78, 000	27, 04, 000
Mining	7, 46, 000	6, 21, 000
Other descriptions.....	1, 12, 00, 000	1, 88, 05, 000

Bombay ranks first for largest imports of machinery, a large proportion being textile machinery. Expansion is becoming general throughout all classes of machinery.

The progressive expansion in the

imports of railway material continues and the figures are the highest on record, the increase during 1906 being 26 per cent. The imports were valued in 1904, Rs. 561, 50,000; in 1905, Rs. 673, 88, 000, and in 1906, Rs. 849, 23, 000. During the twelve months 960¼ miles of railway were opened, whilst on April 1, 1907, 2,873 miles were under construction or sanctioned.

In addition, government stores represented Rs. 893, 46,000, of which 93 per cent. came from the United Kingdom; material for railways represented 48⅓ per cent. of the total.

As regards Ceylon, the importations of merchandise were valued at Rs. 11, 27, 75,000, of which .22 per cent. were from the United Kingdom. Metals, brass, copper, iron, angles, steel, etc., were valued at Rs. 46, 94, 471. The United Kingdom supplied, to the value of machinery, foundry and workshop, Rs. 200, 264; textile, Rs. 33, 872; oil making, Rs. 20, 525; rails and fishplates, Rs. 136, 371, and of government stores, Rs. 27, 92, 671.

(Note.—The rupee can be taken at 1s. 4d., or 30 cents. Thus, Rs. 15.0 equals £1 sterling.)

A HUMOROUS sketch appears in a recent number of our excellent contemporary, the "American Machinist," with reference to safety devices. It describes how an inventor came along with a scheme for preventing accidents in presses or punches, and when the demonstration was made it was found quite impossible to get a hand near the punch at the wrong time; but in the course of trying the device the safety device knocked the inventor off his stool and deposited him on the floor, with compound fracture of both forearms. This may be a fancy sketch, but it has much truth in it. Safety devices may easily introduce worse dangers than they are intended to prevent.

A government inspector of factories has been known to insist on so much guarding about a small gas engine that the attendant was put to considerable risk when starting it. It is very easy to make errors in guarding machinery, and it is very difficult to guard everything. In some machines there must be something left unguarded; only those who have had experience know how difficult it is to avoid accidents and to guard everything, for accidents happen when least expected. The ordinary points of danger are obvious, such as the pair of wheels, the rotating crank—often made much more safe by conversion to a disc crank.

Tangyes, Ltd., have for years built their engines with the disc crank. How many accidents have they not avoided by doing so? Some wheels are not guarded because they turn outwards, but such may drag in waste and break a finger. It seems wise fully to enclose all toothed gears, no matter which way they rotate.

THE Institution of Mining and Metallurgy of Great Britain have adopted certain standard weights and measures. The word ton is to represent a weight of 2,000 pounds avoirdupois, or 29,166.6 troy ounces, and it is advised to drop the use of the hundredweight and quarter, and instead to express fractions of a ton in pounds or in decimals.

The "miner's inch" is a flow of 1.5 cubic feet of water per minute, and "sluice head" represents 60 cubic feet of water per minute; but it is advised to abandon both terms and to express the flow of water in cubic feet, or in gallons per minute or per second. The gallon, as heretofore, is to be the Imperial gallon of 10 pounds of water, as to which it would be desirable if the United States would now reform their gallon as a sort of return for the above reformed ton of 2,000 pounds.

Temperatures are to be expressed in Centigrade degrees. Gold and silver are to be returned as fine gold

or fine silver, and not as bullion, and the gold contents of an ore are to be expressed in money value, as well as by weight, one troy ounce of fine gold being equal to 85 shillings, or to $20.67 United States currency.

With the same circular is published a table of standard laboratory wire screens, giving mesh, wire diameter, aperture and screening area, this being aimed at as nearly as possible to be 25 per cent., which calls for equal breadth of wire and aperture, good interlocking and permanence of aperture. Some of the finer screens can only be woven as twills.

IT has been proposed that tramcars should be supported on more than the usual number of wheels, that such wheels should be rubber-tired, like the wheels of the motor omnibus, that the rails should be a broad band of large granite slabs, and that a single grooved central guide rail would suffice to keep the car in proper time. The success or otherwise of such a system must, of course, depend upon the relative initial cost, and, so far as regards the track, this should probably be less; but the cost of the car, which would probably be greater, wear, tear and maintenance might be much reduced, and perhaps current consumption, on which point trial can alone decide. The idea seems novel, and it appears well calculated to suit small towns which cannot afford the cost of an ordinary electric tramway track.

PRESUMABLY for a long time there will be two schools of practice in regard to the use or non-use of steam in gas producers. When steam is used in a producer the idea, of course, is to utilize some of the heat of the producer otherwise wasted, to produce steam and to decompose it so as to produce a more powerful gas with less percentage of nitrogen, more carbonic oxide and more hydrogen. The opponents of the steam-fed producer would prefer to run at less efficiency, obtaining less hydrogen, a weaker gas not so prone to preignition, and one that will bear a higher compression. Such a gas, they claim, gives a higher efficiency because of its high compression, and there is less of an explosion when it is fired and the pressure in the cylinder is high enough. Progress in gas-engine work has probably been considerably delayed by the attempts to run on steam-engine lines in respect to pressures shown on the indicator diagram. It should not be forgotten that in the steam engine the cylinder is maintained as hot as possible, whereas in the gas engine there is a cold water-jacket, and there is no occasion for an early ignition with the piston standing still and the jacket greedily absorbing all the heat it can get hold of from the burning charge. This heat ought to be converted into work as promptly as possible, and this end is best secured when heat of combustion is generated at the back of a moving piston, not of a dead one.

THE British Fire Prevention Committee during the year 1907 made tests of floor slabs of reinforced concrete which are of considerable interest. The slabs were built up of ⊥ webs with tubes of concrete built in with them to form a slab. Particulars of these tests will be found in the Red Book No. 125, published by the committee. The beams tested had spans of 14 feet, 28 feet and 14 feet, and the strengths shown seem excellent.

A RECENT article by Mr. O. H. Waldt on superheat points out several matters deserving of attention in connection with the use of superheated steam, for turbines more particularly. He says that the construction of turbines should be specially studied with a view to their being made to withstand not less than 350 deg. C. or 662 deg. F., and that the addition of

a superheater ought not to improve the output of a good boiler, whereby it is to be supposed he means there ought not to be so much heat going otherwise to waste, that the superheat is obtained apparently for nothing, for superheat cannot fairly be left off the debit account of the heat ledger, for it does require some, and no inconsiderable amount of heat thoroughly to dry and superheat the steam output of a boiler. He emphasizes the importance of temperature regulation, especially the increase of superheat at light loads, and considers uncontrolled superheaters to be dangerous and often to be useless, and he prefers the independently fired superheater to the flue fired variety, because of the greater facility of control. This hardly applies to the water-controlled type, for with a correct system of water control there appears to be no difficulty in controlling the temperature of superheated steam within any narrow limits.

IT may well be inquired from those who deny cylinder condensation effects on the ground that there is not time for the exchange of heat between the steam and the cylinder metal, if they have ever given a moment's thought to the far more wonderful phenomenon of heat transfer from furnace gases to boiler plates. Furnace gas traveling, perhaps, 50 feet per second, passes a bank of four or five tubes, and parts with, perhaps, 1,200 or even 1,400 deg. F. of temperature in a small fraction of one second of time. It may be quite true that the difference of temperature is greater, but the time is less, and the amount of heat disappearing is enormous. Very little is known, indeed, of the question of heat transfer in boilers, because it is the custom almost invariably to refer the evaporation in a steam boiler to the total heating surface, and in this way sight is lost of the real evaporation from the parts contiguous to the furnace. The maximum rate of evaporation from some portions of a boiler is many times the mean rate, and this forms a good argument for cutting down boiler heating surface and increasing that of the flue feed heater. Plenty of experiments have been made that show the great relative value of the first few inches of tubes in locomotive boilers, and these are doubtless but indications of what goes on in all types of boiler. Water-tube boilers are supposed to give a poor average return per square foot of total heating surface. It would be extremely interesting if some water-tube boiler could be divided into independent sections and the steam output of each section measured, so as to ascertain the relative value of each section. It is not with every water-tube boiler that such an experiment could be attempted, owing to the difficulty of separating the tubes into independent sections.

JOHN HARVARD BILES, LL.D.

A BIOGRAPHICAL SKETCH

AMONGST the prominent men in naval architecture, probably no name is better known than that of Professor J. H. Biles, vice-president of the Institute of Naval Architects. His association with shipbuilding dates back to the time when wooden ships were still being built for the Royal navy, when wooden ships were being protected with armour, and when iron armourclads were experiments. He began practical work on a wooden ship in Portsmouth dockyard, but spent the greater part of his apprenticeship on the building of H. M. S. *Devastation,* the first battleship deliberately constructed without sails, a vessel designed by Sir E. J. Reed, into whose shoes he has since stepped as consulting naval architect to the India Office. Passing on to the Royal School of Naval Architecture, at South Kensington, and the Royal Naval College, at Greenwich, he was graduated first of his year, and was appointed a junior on the construction of the cruisers *Iris* and *Mercury* at Pembroke. These vessels were the first to be made of the present-day mild steel, and it is not too much to say that their successful construction was the beginning of a complete reconstruction of vessels for the mercantile marine. While they were building they were alone in having that steel. Within ten years the use of iron as the main structural material of ships had been completely abandoned. From the construction of these steel ships in Pembroke dockyard to the manufacture of the material in the Landore Steel Works was an interesting and useful change in his experience, bringing him into contact with the most advanced steel metallurgists and manufacturers. From there he passed to the Admiralty office, assisting in warship design and special scientific inquiry, including the series of turning trials of H. M. S. *Thunderer* made for the *Inflexible* committee under the direction of Sir Philip Watts. In 1880 Mr. Biles accepted an invitation to become naval architect to the Clydebank shipbuilding firm now known as John Brown & Co. His studies in the resistance of ships while at the Admiralty led him to change very considerably the practice as to forms and dimensions of merchant ships which had made the Clydebank firm famous. The *Servia* was then building for the Cunard Company, having dimensions 515 feet by 51 feet, and ten beams in length. A duplicate was being inquired for by the owners, but they were persuaded to adopt Professor Biles' proposal of a vessel 470 feet long by 57 feet beam, of eight beams, but of finer form. Such extravagance in beam was generally condemned, but the result showed that a higher efficiency followed. The same innovation was applied in many other types of vessels, one of the most notable being the *America,* built for the National Company, to compete with the existing Atlantic ships of that time. This vessel averaged the same speed as the fastest existing ships for 20 per cent. less power and coal consumption. She was the forerunner of the *New York* and *Paris,* the first fast passenger twin-screw Atlantic vessels. The contract for these vessels was placed in 1887, and they are running successfully to-day. Their un-

der-water form is practically identically the same as that adopted for the *Lusitania* and *Mauretania,* which was selected for them after a most extensive series of experiments had been made in the Admiralty and other testing tanks. The *New York* and *Paris* embodied the first attempt at complete sub-division, i. e., complete watertight bulkheads with no doors, as Professor Biles believed that doors in a bulkhead were a danger. The value of this sub-division has been more than once shown in cases of emergency in these ships, and the fact that the *Dreadnought* and all later battleships and cruisers have the same system is some indication of the progressive nature of the work done by Professor Biles at Clydebank.

The warship side of naval construction had been equally interesting him during this period. The first torpedo-boat destroyer, *Destructor,* was designed by him, and many valuable features were introduced to increase safety and speed. This vessel did a passage from Falmouth to Finisterre at a speed of 20 knots, which, though it happened twenty years ago, has seldom, if ever, been equalled by a destroyer. The cruiser *Reina Regente,* designed by him at that time, was the fastest of her day—in fact, the first cruiser to exceed 20 knots in speed. Her subdivision was very extensive and her armament and protection greater than any ship of her time and class.

One of the most successful of the earlier intermediate steamers was the *Friesland.* She attained a trial trip speed of 14½ knots, fully laden, and averaged for many years 15 knots across the Atlantic on a very moderate coal consumption.

During the time he was at Clydebank Mr. Biles contributed many papers to the Institution of Naval Architects on various scientific and practical subjects, and was elected to the council of that institution, upon which he has remained ever since. Later, he was elected a vice-president, and has taken a very active interest in the management of that institution.

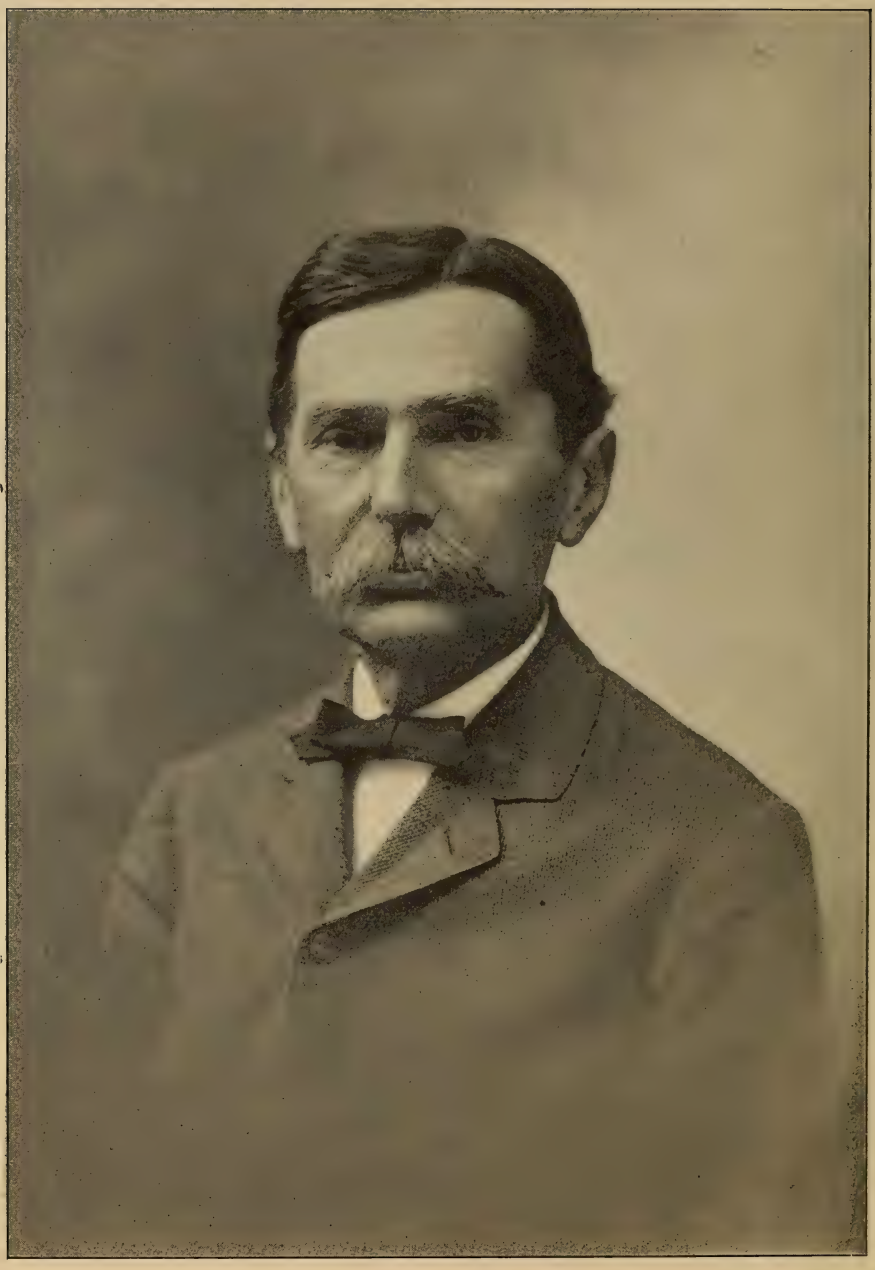
After having been at Clydebank for ten years Mr. Biles was appointed professor of naval architecture at Glasgow University. Students of naval architecture come from all parts of the world to take the courses of lectures in that famous Scottish seat of learning. During the last session American, Japanese, Chinese, German, Scandinavian, Russian, Austrian, Roumanian and British students formed a cosmopolitan gathering, united in the one object of learning naval architecture. Two Scotsmen headed the senior class in the finals, but this position has been taken, in turn, by many nationalities. The present chief constructor of the United States Navy, Admiral Capps, was one of these graduates. Constructors Hibbs, Rock, Ruhn, Spear, Ferguson, Watt, Zahn, Powell, Evans, Robinson, besides many other Americans in private service, have been graduated at Glasgow. Also Yacht Designers Barbey, Stearns, Clinton, Crane and Wittlesea took the naval architecture courses. Professor Sadler, of Michigan University, was a graduate, and afterwards assistant to Professor Biles. Mr. W. Selkirk Owen, of New York, another graduate, occupies that position at present. Yale University has recognized the work of Professor Biles by giving him the degree of LL.D. Professor Terano, one of the staff of the naval architecture department of Tokyo University, headed his class at Glasgow University. Many other Japanese have distinguished themselves. Professor Biles was elected an honourary member of the Japanese Society of Naval Architects in 1903.

As professor, he has not been allowed to drop out of touch with the practical world, his services being retained as consulting naval architect by such companies as the L. & S. W. Railway, the Midland Railway, the American Line, Union Steamship Company, of New Zealand; Great

Northern Railway, of America, and others, for whom he has designed many steamers, now successfully running. His recent appointment as consulting naval architect to the India Office, in succession to the late Sir E. J. Reed (formerly chief constructor of the Navy), will give him a further field for the practical application of his scientific knowledge. The Admiralty have availed themselves of his professional skill in investigations on mercantile auxiliaries, the outcome of which inquiry was the *Lusitania* and *Mauretania;* in investigations of the strength of torpedo-boat destroyers, on which occasion for the first time the absolute strength of a vessel was tested in dock, so that afterwards the amount of stress the sea brought upon the vessel could be determined; and latterly on the warship design committee, where, though its secrets have not yet been divulged, we do not doubt that he contributed his full share to the success of the vessels produced by that committee. He was a member of a committee on tonnage of ships in 1905 and 1906. One of Professor Biles' most interesting pieces of work was the devising and carrying through the reconstruction of the Egyptian yacht *Mahroussa,* an iron paddle vessel built forty years ago, but now an up-to-date turbine steamer. This work was entrusted to him by the Khedive, and as a mark of his Highness's appreciation of the result, the Order of the Osmanieh of the third class was conferred upon him. He is a prolific writer for scientific societies, his papers and speeches being known for their practical character. He published a series of lectures on "Steam Turbines" in book-form last year, and is on the point of publishing the first volume of the systematic treatise on naval architecture which he has been evolving from his regular lecture course.

His professional work has taken him to many parts of the world to advise or receive instructions in connection with designs of ships and other professional work. Japan, China and the United States of America have been many times visited. His first visit to the East was made in connection with new warships to be built for Japan soon after the China war, and he was afforded the fullest opportunity of seeing the results of gun-fire upon the ships that had taken part in the battle of the Yalu.

Professor Biles is a member of the Institution of Civil Engineers, member of the Institution of Mechanical Engineers, and member of the Society of Naval Architects and Marine Engineers, U. S. A.



PHOTOGRAPH BY PACH BROS., NEW YORK

MATTHIAS NACE FORNEY

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CASSIER'S MAGAZINE

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THE FIRE DEPARTMENT AND THE HIGH-PRESSURE SYSTEM

By Peter J. McKeon

IT is curious that those who are the strongest advocates of salt water or high pressure fire systems (the two are synonymous to many people) are insurance men, water engineers and commercial organizations. The firemen themselves are not so loud in asking for special water supply, an attitude that does not mean that firemen do not know the needs of their business; they know them far better than outsiders and, for this reason, are more anxious about other things than the water supply.

A good water supply—that is, an abundant quantity of water, a sufficient number of hydrants, and water at a necessary pressure—is one of the essentials of good fire department work, but it is not the only one nor the most important. The personnel of the department, including the character, ability, training, experience and *esprit de corps* of the officers and men, is the great thing, and, if this is defective or deteriorating, the loss will not be made up by the water supply nor by the mechanical equipment. This fact is to be remembered in forming an estimate of the value of the new high-pressure water supply system, as installed in New York City, Brooklyn, Philadelphia, Cleveland and Coney Island, and which is being planned for many other cities.

The high-pressure system is intended to do away with or supplement the use of fire engines or steamers. The fire engine, practically speaking, is simply a force pump on wheels. It is the natural successor of a huge syringe in the hands of a London alderman and the hand-engine worked by gangs of red-shirted volunteers. A further step in the evolution of fire fighting is the displacement of the traveling pump by the fixed pump; in other words, the high-pressure pumping station becomes the modern fire engine.

The fire engine or steamer to-day is used where a water supply is not under sufficient pressure to meet the fire department's needs. Water is almost universally used as the extinguishing agent and, except where taken from tanks containing sulphuric acid and bicarbonate of soda, what are commonly known as chemical engines or extinguishers, it is obtained from the regular water supply of the community, or from natural water sources.

For fire purposes, the water mains are tapped at intervals and fire

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hydrants set in place. To these hydrants the firemen attach their hose direct, if there is sufficient pressure, or, if not, attach an engine, which draws water from the hydrant and, with its pumps, forces it through the lines of hose.

The hose is a flexible pipe, usually of rubber, made in convenient lengths, usually 50 feet, with metal couplings at the ends, so that the lengths can be joined together to make a long line. At the end of a line of hose the firemen attach a nozzle or pipe, which is used to direct the stream of water.

The water supply, the hydrants and the hose are part of every fire department. The point of difference is in the method of getting pressure or head to the streams of water. This is done in three ways—by gravity, by the fire engine and by pumping stations.

The gravity system takes advantage of a well-known physical law, that water will rise to its level; in other words, a column of water, descending from a higher to a lower level, acquires in its descent sufficient momentum to ascend almost to the level from which it started, the difference being due to friction in the pipes, which causes a "loss of head." As carried out in gravity water supply systems, the source of supply is a lake, pond or reservoir on a hill above the town, or it may be a high, vertical tank, called a standpipe, to the top of which water is pumped, and after its fall turned into the distribution mains. If the water descends 200 feet, it will rise almost to that same height under the pressure acquired in its descent, so in places where a gravity water supply is available the firemen obtain, directly from the hydrants, streams of water that they can throw over the roofs of the highest houses, which meets the requirements of fire fighting, so far as pressure is concerned.

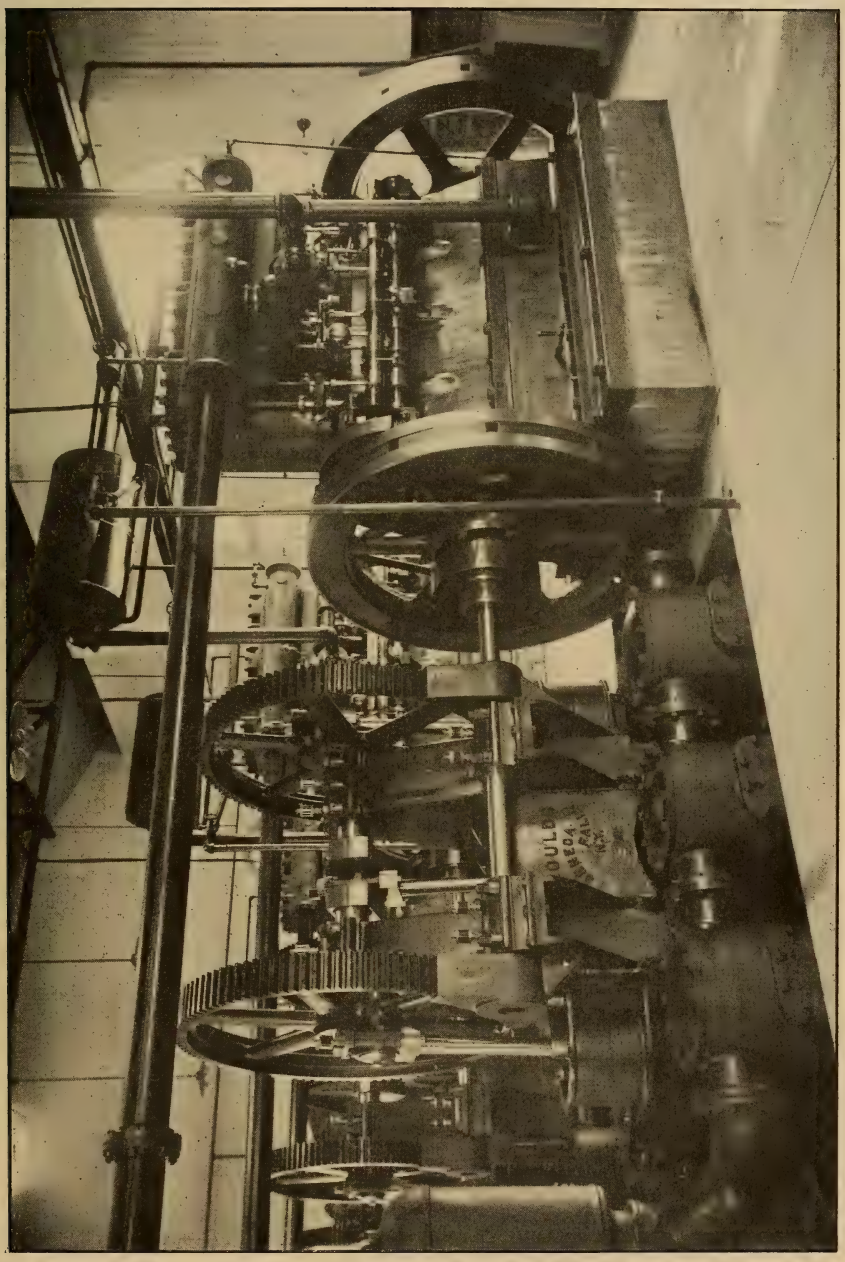
When the natural pressure is not sufficient, the fire engine is called into service. This is simply a force pump on wheels, whose purpose and use is to force water to the distance and height required by the firemen. The pump is usually worked by a steam engine, although gasoline engines are in use, and electric motors have also been suggested for the purpose.

Instead of the fire engine, or traveling pump, which must be taken to every fire, the fixed pump is another method of supplying the necessary pressure. The fixed pump converts a low-pressure system into a high-pressure system; that is, it forces water through pipes and hydrants at a pressure sufficient for fire extinguishing purposes; in other words, does what gravity does—makes unnecessary the presence of fire engines at the hydrants.

These different methods of obtaining pressure have been in use for a long time; but a recent development is what is known as the salt water, or high-pressure system, such as is already (1907) in operation at Philadelphia and Coney Island, and, in 1908, will be in use in New York City and Brooklyn. In these cities fire engines have heretofore been used, so the introduction of the fixed pump system is of interest.

For many years, in New York city, there has been an agitation for a salt-water system for the use of the fire department. This was urged principally by insurance men and business organizations, who seemed to think that such a system was a panacea for the fire evil, or at least a sure cure for the conflagration danger.

Both of these classes of influential citizens have little or no first-hand knowledge of how the fire department does its work, and their principal source of information is the daily newspapers. Newspaper reports about fires cover principally the news feature, so they cannot be depended upon for correctly describing fire department operations, and this appears in the almost general publication, after a large fire, of statements about no water or low pressure.



HIGH-PRESSURE PUMPING STATION, NEW YORK CITY. NASH GAS ENGINE; GOULD TRIPLE-PLUNGER PUMP

On newspaper reports, many people believe that the water supply for fire department use is extremely deficient. It is true that, in certain portions of the city, the hydrants, the quantity and the pressure of water are not what they should be; but, on the other hand, a proper investigation of many large fires would show a good water supply available.

The reported deficiency was due to many engines drawing from the same main. As the engine companies arrived at a fire, they took hydrants haphazard and without regard to the capacity of the mains, or how many engines were already drawing from them. In the case of 6 and 12-inch mains, it did not take very many engines to use up the water, with the result that some engines got little or no water, which also happened when a big engine and a little engine were both drawing from a small-size main. In respect to this trouble, it might be claimed that some effort should be made to locate the engines to good advantage or, adversely, it might be claimed that the water supply system should be able to supply all the engines, regardless of how they took hydrants.

The net result, however, was a belief in the deficiency of the fire department water supply, and a new system was proposed, commonly known as the salt-water system. As installed, however, the system is a fresh-water, not a salt-water system, except in the emergency of the Croton supply running dry, or the fire-boats being called on to help the pumping stations; that is, the pumping stations will draw fresh water from the Croton mains and pump it into the new high-pressure mains as long as the Croton supply lasts. If this fails, then the pumps will draw salt water from the rivers and pump this salt water into the high-pressure mains. In case the fire-boats are pressed into service as an auxiliary pumping station, they, of course, will pump salt water.

The system, as installed, consists of special hydrants fitted to a separate system of mains, entirely distinct from the present Croton water hydrant mains. The new mains are connected to two pumping stations, each containing five centrifugal pumps, each of which can pump 3,000 gallons of water per minute. As the pumps discharge the water, it will have a pressure of 300 pounds per square inch. When it reaches a point midway between the stations the pressure is estimated at 250 pounds; that is, it has lost 50 pounds pressure in its journey through the mains. In passing through the hydrant it will lose 15 pounds more, so that, as it issues from the hydrant, the pressure will be 235 pounds. These pressure figures are computed according to formulæ and for a given location, and would be greater or less as the place of delivery was nearer or further from the pumping station. The figures are also subject to correction according as the pumps discharge the water at less than 300 pounds pressure.

The stated pressure of 235 pounds at the hydrant nozzle is what might be called the standard, and gives a basis for comparison with the fire engines; for, with the pumps working at their rated capacity, that pressure at least should be available. Taking this pressure of 235 pounds for purposes of comparison, what can be said of it? It is much less than the engines can do, for, at several standpipe tests, the engines have worked up to 280 pounds water pressure, and while working at fires have developed 270 pounds water pressure. On the other hand, the average working pressure of engines at fires is put by fire department engineers at 200 pounds, though it is not at all unusual for engines to maintain an average pressure of 225 to 250 pounds. In respect to a high average working pressure, if the high-pressure system can maintain 235 pounds at the hydrant nozzle, it will prove superior to the fire engines as a whole.

HIGH-PRESSURE FIRE STREAMS IN SERVICE

How about the quantity of water? By the addition of pumping units and the assistance of the fireboats, the high pressure system could deliver an immense quantity of water, but figuring on only what the two stations are at present equipped to do, that is, 30,000 gallons per minute, the question is, how does this quantity compare with what the engines could do?

Fire engines are rated in capacity from 500 to 1,400 gallons per minute, depending upon the size of their pumps. The fire engines in the high pressure district are either 1,400 or 1,200 gallon engines, so, on their rated capacities, it would require about 25 engines to pump 30,000 gallons per minute.

Under actual working conditions, however, these engines are not expected to pump more than 800 gallons per minute, so it may be said that 37 engines equal the rated capacity of the high pressure pumping station. On the other hand, it is not expected that the pumping stations will maintain their maximum capacity, and, making allowance also for some leakage, it is a fair estimate to say, that 30 engines are equal to the pumping stations, with 10 pumps in the two stations. On this basis, it appears that high pressure system if used alone, is about sufficient for a fifth-alarm fire, or a 9-9 alarm fire.

For fires of this magnitude, water should be provided for the operation of at least two water towers, each with two 2-inch nozzles and from twenty-five to thirty 3-inch hose lines with 1½-inch nozzles. With a constant pressure at the hydrant nozzles of approximately 235 pounds, the quantity of water used would be very considerable, probably more than has ever been used at a fire in New York, so that an allowance of 1,200 gallons for each 2-inch nozzle, and 800 gallons for each 1½-inch nozzle would seem reasonable. This would make a water consumption of from 25,000 to 30,000 gallons. In other words, the high pressure system cannot be expected to supply enough water for anything more than one 9-9 alarm fire. In case of another

MANNING A PIPE FROM A HIGH-PRESSURE HYDRANT

large fire at the same time, or of several simultaneous large fires, such as, three third-alarm fires, or one fourth-alarm fire and one fifth-alarm fire, the high pressure system alone would be inadequate, and the fireboats would have to assist, or the engines be used and draw the water from the low pressure Croton mains.

The operation of the high pressure system presents some new and interesting fire department problems. The fire department has been trained to the use of hose lines supplied by the fire engines, which made it possible to regulate the pressure for each line and therefore operate each line independently. The high pressure lines will differ from the fire engine lines in that the pressure will be fixed and constant and unless some way is found to regulate the pressure at the hydrant all the hose lines in use at a fire will work under the same pressure. Is this going to work?

The water engineer's work ends where the fire engineer's work begins. The water engineer's and the insurance man's idea of a fire stream is not shared by the fire engineer. The former think in terms of water; a stream is so much water under a certain pressure shooting from a nozzle. This answers for tests and

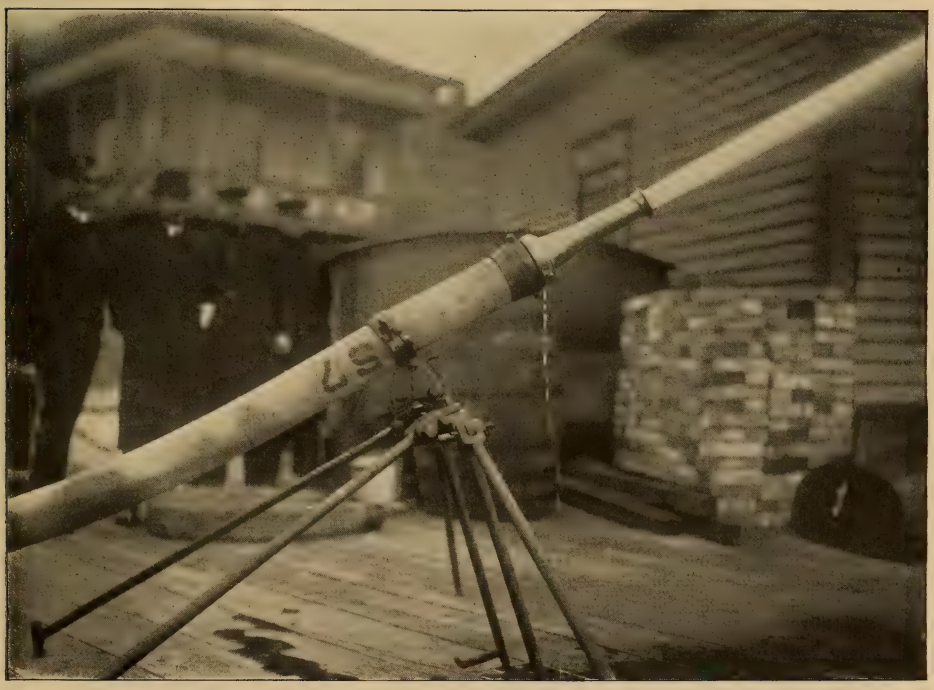
exhibitions, but for the real work of putting out a fire, a stream is a different proposition.

The fire engineer does not think in "streams"; he thinks in lines, hose lines, and what he has to figure on in his work is to get the line near the fire. This means making the connection at the engine or hydrant, stretching the hose to the building and then "jackassing" it up a stairway, or fire escape, into another building, on a roof, or over fences and walls, a process that is slow work and hard work.

After the line is in position and the pipe or nozzle attached, the handling of the pipe may not be so easy. With a good pressure, it takes two or more men to hold it; these men have to be relieved; the pipe or line may have to be shifted, the men may have to back away from their position; the pressure may have to be raised or reduced; all of these contingencies arise at a fire, so that the effective operation of one line usually needs the services of a full company of men, as well as the guiding head of a chief officer.

Fire department work may be distinguished as inside work and outside work. The former means taking hose lines into buildings and getting the pipe at work close to the fire. The latter is fighting fire from the street, what is called, in derision, the "Darktown Fire Brigade at Work." Volunteer firemen, and often paid firemen in some cases, depend on street fighting. If there is much smoke or the fire has some headway, their lack of experience or disinclination to "take punishment" keeps them from entering the building.

The best city firemen, such as the picked "working" companies in the New York fire department, enter buildings and give the fire a fight at close quarters. If they cannot stay on the floor they back out to doorways, or fire escapes, or if driven from these, they retreat to roofs and windows in other buildings, until the



HIGH-PRESSURE HOSE LINE WITH HOLDER FOR OPERATION WITHOUT CONTROL BY MEN

Hose, 3½ inches; nozzle, 1¾ inches; pressure at nozzle, 120 pounds. Pipe holder designed by John Kenton, Chief of Battalion, New York Fire Department.

water tower has "darkened" the fire sufficiently for them to re-enter the building, or the building collapses.

This close hand method of fighting fire requires that hose lines must be quickly stretched and be moved about. At first-alarm fires in New York city, it is a rule for the engineers to start with 75 pounds at the pump, which usually gives at the pipe a pressure of 15 to 25 pounds. This permits the use of a controlling nozzle, and the handling of it by one man, while the line can also be moved about on a floor, carried up or down stairs, or shifted as is needed to follow the fire.

At second or greater alarm fires, the pressure at the nozzle is greater, sometimes as high as the engine can give. In this case, the pipe is usually fastened, so that two men can handle it and the line can be moved about to some extent. It is not always possible, however, to tie down a pipe and in some cases the company may be operating in a position where the men must have a chance to back out instantly, and this requires control of the line.

For such operations, the hose line supplied by the fire engine gives a mobility and control which at first sight does not seem provided by the lines supplied by the high pressure system. In other words, how are the high pressure lines to be regulated, so that each line can be operated independently? This is not so necessary for the fixed lines, those used in water towers, standpipes, automatic sprinklers, and street pipes, which should stand whatever pressure the pumping station can give. But it is necessary for the movable lines, which have to be handled by the firemen inside of buildings. For the movable lines a pressure from 235 pounds to 250 pounds at the hydrant is not entirely safe, while the use of patent self-controlling nozzles, pipe sticks, etc., may be too heavy and cumbersome for the lines which have to be taken into buildings. Various suggestions for overcoming this difficulty are advanced, but all of them mean reducing the pressure, or reducing the quantity, either of which may affect the efficiency of the streams and thereby to a greater or less extent nullify the value of the high pressure system.

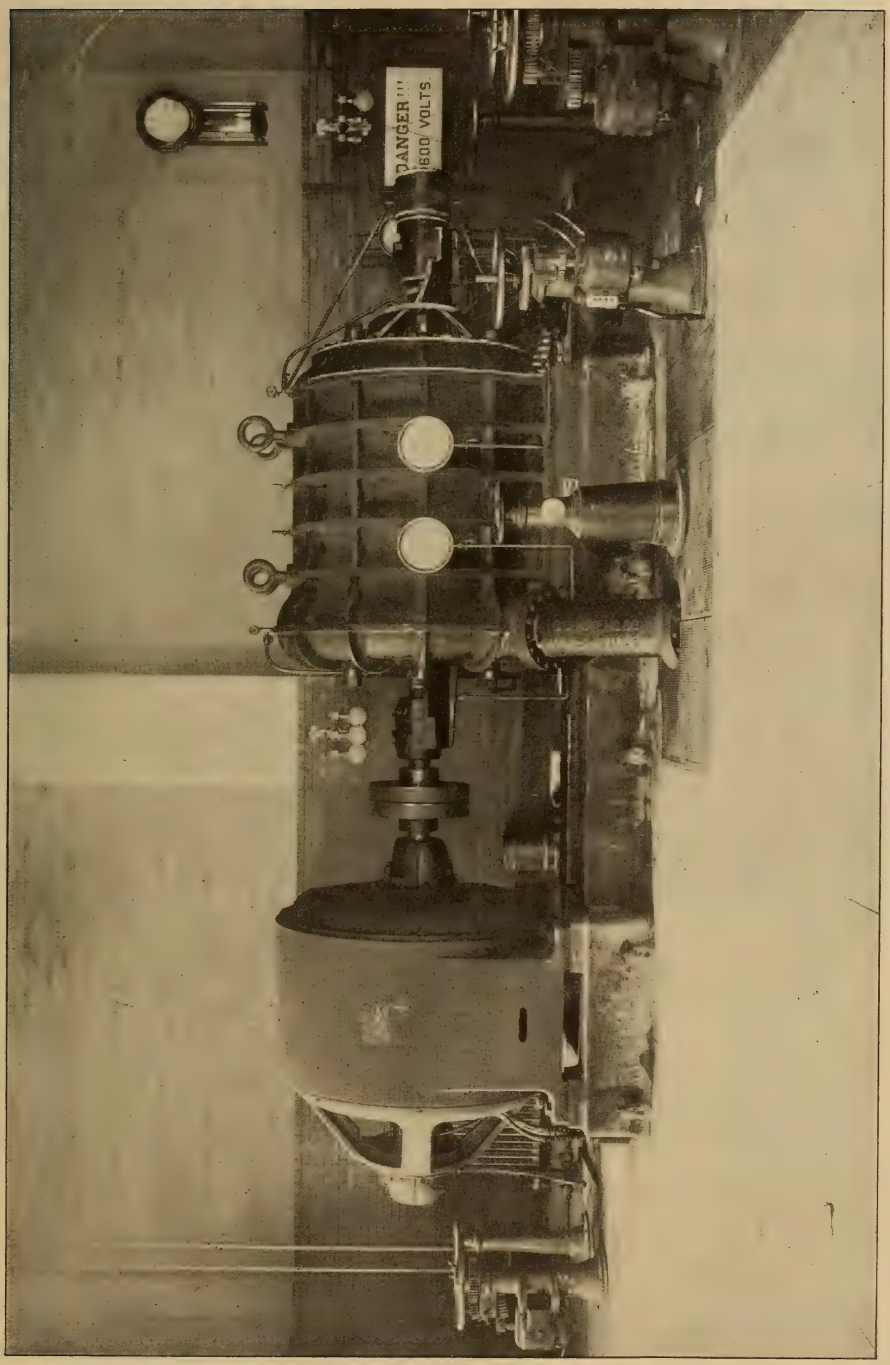
What effect has the high pressure system on the conflagration danger? This is a thing most people want to know; for, apparently, the system has been advocated and installed in the belief that it meant the elimination of the conflagration.

A conflgration, or any large fire for that matter, is such a freakish and uncertain phenomenon, that those who know most about fire have the least inclination to prognosticate about it. As regards the high pressure system, it must be remembered, and too much emphasis cannot be laid on the statement, that the chief factor in standing off a conflagration, as far as the fire department is concerned, is the personnel.

The high pressure system certainly reduces the chance of a conflagration, because it improves the likelihood that the firemen will hold a large fire. If it did nothing else, it provides an auxiliary low pressure water supply and makes useless hereafter the oft-repeated excuse of no water or low pressure. As a conflagration stop its chief value perhaps will be in furnishing powerful streams which can be used to prevent a fire from crossing the street, by wetting down or forming a water curtain to protect threatened buildings.

In a conflagration, the crucial point is when a large building on fire begins to set fire to the surrounding buildings. In such an emergency the ability to concentrate a number of powerful streams, such as would be made by 1½-inch or 2-inch nozzles, with a nozzle pressure of 100 to 150 pounds would be a very favourable factor, and it is believed by many fire department engineers that such streams would suffice to check almost any fire.

Such an operation, it must be



HIGH-PRESSURE PUMPING STATION, NEW YORK. ELECTRIC MOTORS AND MULTIPLE-STAGE CENTRIFUGAL PUMPS. 300 POUNDS PRESSURE. 800 H. P.
D'OLIER ENGINEERING CO., NEW YORK

pointed out, is more likely to be successful if the fire is extending in front; that is, across a street. At the front of a fire, all the companies report, it is easer to locate them to advantage, and there is also room to concentrate hose lines and apparatus. On the other hand, if the fire is extending at the rear, that is across an alley or into buildings which back up on the original fire, the conditions may not be so favourable.

Even if the immediate vicinity of the fire can be protected with sufficient hose lines, there still remains the very probable chance, that a conflagration may get under way. This is due to the fact that fire will jump some distance from its original location, perhaps as far as several blocks, either by great volumes of heat attacking buildings, or by brands dropping in buildings and starting additional fires. Such a contingency makes it unwise to declare that the high pressure system is a conflagration cure, simply because it provides enough lines to cover one large fire.

On the subject of block fires, the Chief Engineer makes an interesting statement. He says: "If any block were on fire, sixty streams of 500 gallons each could be concentrated on the block." As a matter of hydraulic arithmetic, this is manifestly correct; but, as a fire department calculation, it is worthy of scrutiny. A New York city block on fire is a tremendous possibility and if this occurred, fire engineers know that it would not be one block, but the contiguous blocks as well that would be burning. To cover such a fire, there would be needed not only sixty lines, but probably twice sixty. For each line a company is needed (this is a practical fire department estimate), so nearly the entire fire department of New York would be required. There would be hydrants enough to supply all these companies, but how about the water? Consider the present equipment alone, that is, water-tower, deck-pipes, and hose lines. Assume that the pumping station is delivering water with a pressure at the hydrant nozzle of 235 pounds, and calculate the quantity used by the present fire department tables of water consumption, which allows 800 gallons for each line and 1,200 gallons for each

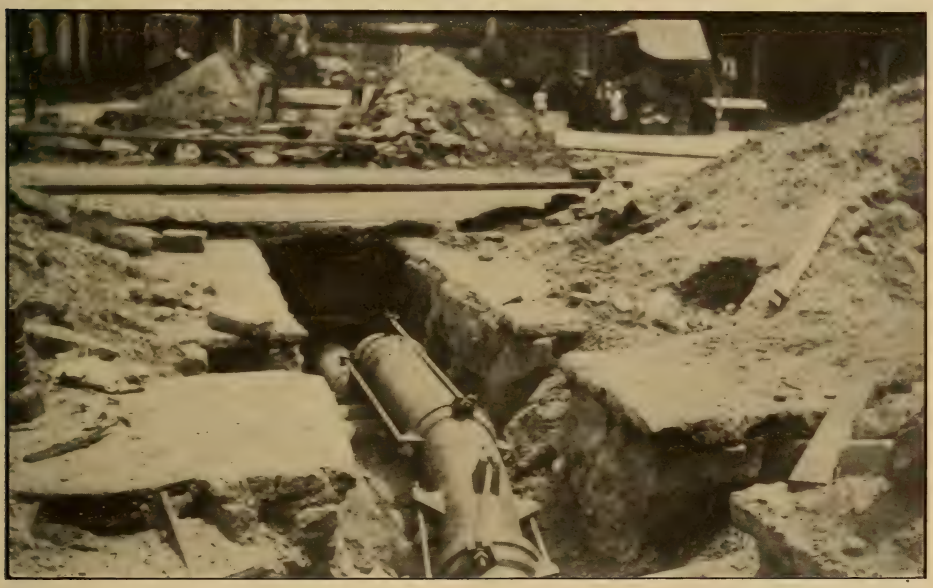
DIFFICULTIES IN LAYING HIGH-PRESSURE MAINS. INTERSECTIONS OF OTHER PIPES AND CONDUITS

water-tower pipe that may be used.

New York city has six water-tower apparatus, and undoubtedly all would be called for such a fire. Each apparatus has a tower-pipe and a deck-pipe, making 12 pipes in all and, at 1,200 gallons discharge for each pipe, would make a total of nearly 14,400 gallons per minute. Then assuming that 60 lines are working at 800 gallons per line, gives a total of 48,000 gallons per minute, or a total water consumption for a block fire of 24,000 gallons a minute.

The high pressure pumping stations, as installed, have a rated capacity of 30,000 gallons per minute and, with the additional six pumping units planned for, the capacity would be increased to 48,000 gallons. For a block fire, it would then be necessary to call on the fire-boats, whose pumping capacity is rated at approximately 50,000 gallons, so, with their assistance, enough water could be obtained from the high pressure mains without using the engines.

Such calculations for a block fire may seem fanciful, but it is well to compare them with the operations at an actual fire which, in area and magnitude, was only a small portion of a block. Within ten years, the worst "conflagration" New York has had, was, all things considered, probably the fire in Herrman's furniture factory, at Mott street, near Broome street, December 21, 1903. This was a seven-story fireproof building, filled with the inflammable materials of a furniture wood-worker. It was surrounded on all sides by low tenements and, when the commanding officer of the fire department arrived, the building was a mass of flame. It was a true conflagration situation, and the thing to do was to let the building burn and protect the surroundings. Through the ability of the officer and the favourable weather conditions, the fire was confined to the building in which it started, a result that is universally conceded to have been due to a happy combination of circumstances. For this fire, three water towers and thirty-six engine companies were called, while the number of lines stretched numbered thirty. If this number were used for a near-conflagration (and it is



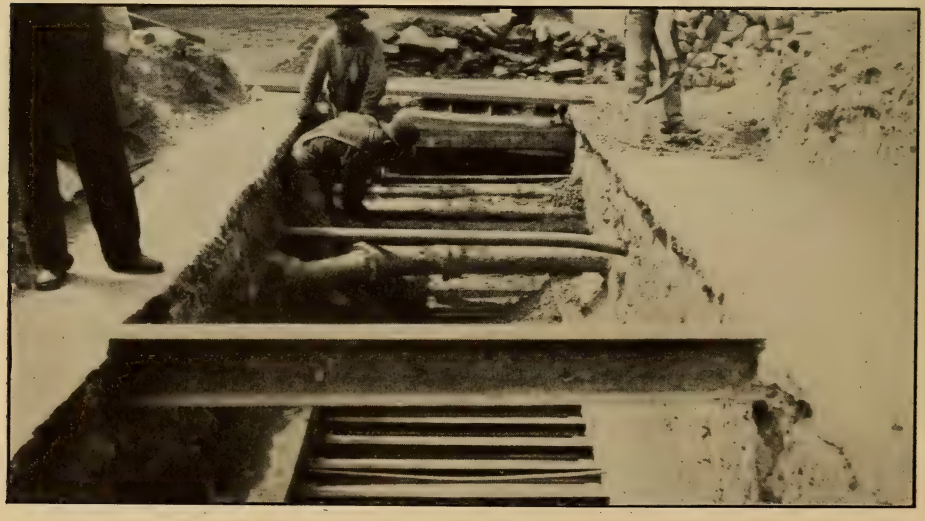
REINFORCEMENT OF HIGH-PRESSURE MAIN AT A BEND

probable that every 9-9 alarm fire would require about the same number of lines) it is obvious that a fire that got away from the department (a real conflagration) would require considerably more than 30 lines. Every year New York City has two or more fifth-alarm fires, for which there respond about 27 engine companies and one water tower, while another tower is usually summoned by special call. The number of lines in operation number from 20 to 25, which at 800 gallons per line would mean a quantity of 16,000 to 20,000 gallons. If this quantity is needed for an ordinary large fire, it is evident that a capacity of 30,000 gallons for the high pressure system does not allow much for a factor of safety.

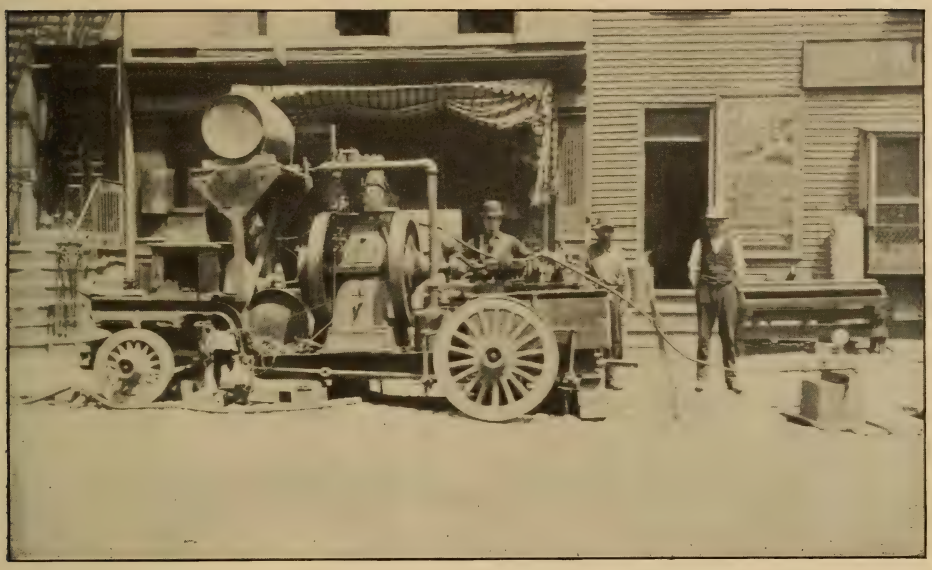
For this reason, it would seem advisable to duplicate the system or increase its capacity considerably, if dependence is to be placed on it to the exclusion of the fire engines. Is it practicable to do away with the fire engines? The best officers in the New York fire department believe that it is. There is no reason why in quantity and pressure of water, pumping stations cannot give as good fire streams as the engines. One thing that is needed, however, is some means of regulating the pressure at the hydrant nozzles, so that every hose line can be operated independently.

It must be recognized, however, that the displacing of the fire engines means dependence on a single source for both quantity of water and necessary pressure. With the fire engines in use, the breakdown of one or two engines means the loss of one or two hose lines, which can be made up by the other engines. A break-down of a high pressure pumping station, howeever, would mean the loss of both supply and pressure for a number of lines, and such an accident might carry with it tremendous possibilities, if it happened while a dangerous fire was in progress. The chances of such an accident, of course, could be practically eliminated by a duplication of the pumping stations and the reduction of the area supplied by each station.

A natural question suggested by the above is: What is the high pressure system for? Is it to take the place of the fire engines? Is it to be an auxiliary to the fire engines, to the extent of supplying streams at extra heavy pressures? Is it to be used by



CHANGING THE ROOF OF THE NEW YORK SUBWAY TO ALLOW ROOM FOR HIGH-PRESSURE MAINS



PORTABLE GAS ENGINE AND PUMP USED IN TESTING HIGH-PRESSURE MAINS

the fire department as a separate system in conjunction with the present engines?

If the high pressure system is to be used simply for supplying water towers, automatic sprinklers, standpipes, and street streams, the provision of hose wagons with special hose, as is now done for the fire boats, would answer the purpose.

If the high pressure system is to be used wholly or in part to supply the hose lines to be taken into buildings, it means the organization of some or all the fire department companies as high pressure companies. For it is believed to be hardly practicable to have the same companies work with both systems. In any case, the high-pressure system presents some new and interesting fire department problems and probably means a certain amount of reorganization. The development certainly ought to proceed with a view to displacing the fire engines, as these are costly and cumbersome beyond their efficiency.

The high pressure system, unfortunately, was planned and installed without much co-operation on the part of the fire department, so that it is to be turned over to the firemen without any very definite idea of its use and purpose. No plans have yet been announced by the fire department beyond specifications for hose wagons and special hose, so that from all appearances the system will have to work out its own sphere of usefulness.

In the planning of the high-pressure system the neglect of fire department knowledge and experience is shown by the fact that provision was not made for hose connections on the roofs and at the rear of buildings, a suggestion that was advanced fully ten years ago by Deputy Commissioner Hugh Bonner, at that time Chief of the department. These connections would save the stretching of much hose, a factor in fire department operations that is only fully appreciated by fire department officers.

In addition, the distribution and location of the hydrants were made without the fire department supervision. Indeed, it is reported that the judgment of insurance men, who are notoriously lacking in a practical understanding of fire department operations, was preferred to the knowledge and experience of the men who, in case of a conflagration, will have

the duty and responsibility of stopping the fire.

Another omission, equally if not more serious, is the failure to provide for connections to automatic sprinkler systems. The installation of this effective device in buildings—beyond doubt the most effective means of controlling fires—is one of the surest preventives of conflagrations. The cost of these systems, however, usually prevents their more general use. In respect to cost, however, a large item is the installation of tanks as primary and secondary water supplies. There appears to be no mechanical or engineering difficulty in the way of utilizing the high-pressure system as a secondary or even a primary water supply.

If the high-pressure system had been planned to supply automatic sprinkler systems, this one thing alone would go a long ways toward reimbursing the people of New York for their expenditure of millions for the system. That this excellent feature was not considered, is not so much the fault of the water department engineers, who planned the system, nor the business organizations who advocated it; but it is the fault of the insurance companies of New York. These companies maintain special departments for the control and supervision of automatic sprinkler equipments, and they should have taken steps to see that the high-pressure system was planned to assist in the installation of automatic sprinklers. This would not only have been of benefit to the insurance companies themselves, in the safeguard it threw around their undertaking, but it would have benefited the public as a conflagration measure, and also reduced the cost of insurance within the high-pressure district to a very considerable extent.

At the present date, February, 1908, the high-pressure system has progressed to the extent that in the Borough of Manhattan all the mains are laid, except a small section, which must await the completion of the Centre street subway. The hydrants, except an additional 200, are all set, and in part of the district the mains contain water at the Croton pressure, and have already been used by fire engines at several fires. In the South street station the pumps and motors are being assembled, and the contractors estimate that, by February 1, they will try the pumps, by March 1 they will test the system and, if nothing intervenes, will put the system in service by April 1. The West street station, it is estimated, will take about sixty days longer than the South street station. In Brooklyn, the high pressure system is somewhat in advance of that in Manhattan, as it was possible to test one of the pumping stations in the latter part of January.

THE INSURANCE OF ELECTRICAL PLANT AGAINST BREAKDOWN

By William R. Bowker

THE insurance of electrical machinery against breakdown is becoming very extensive in Great Britain. The principal insurance companies who do the bulk of the business are located in Manchester. They are the Vulcan Boiler Insurance Company, Ltd., the National Boiler & General Insurance Company, Ltd., and the British Engine & Boiler Insurance Company, Ltd.

At one time the three companies suffered financially as the result of severe competition one against the other, and the natural outcome was the formation of an agreement as regards the rate tariff. Each company is separate and independent of the others in regard to all their other business. There is no combination or merging of interests outside of the question of "premium rates."

Each of these firms, in addition to the insurance of electrical plants, do an extensive insurance business in regard to boilers, engines (gas, oil, steam and turbines), gas producers, central and power plants, etc., employers' liability insurance, and each does a considerable amount of consulting and inspection work, such as giving advice on power station schemes, fitting up of mills, factories, etc., the testing of boilers and materials, and the inspection of machinery under construction and the testing thereof. They number amongst their insured and other clients an extensive connection with municipal, private power and central station plants, collieries, steel works, ship-building yards, workshops, engineering establishments, textile and other mills, co-operative societies, small users, etc., and have on their insured lists hundreds of crane motors used in foundries, engineering work shops, timber yards and elsewhere.

None of them will under any circumstances insure electric coal-cutters against breakdown, the financial risk being too great.

The insurance of plant, machinery, etc., is only against legitimate breakdown as the result of accident and, as an additional inducement to obtain business, they insure the buildings in which the plant is located against damage to surrounding property directly caused by any fragments of machinery that flies apart; for instance, if the fly-wheel of a gas engine were to break, and a part flew off and broke through a wall or roof of the building, or came into contact with other machinery and damaged it, they would pay the cost of damage done to the surrounding property in addition to the cost of repair of the gas engine; i. e., within the limits of the insured amount. As an example, if a gas engine and surrounding property in combination were insured for £500, the insurance company would pay the full extent of the damage up to that sum of money. None of these companies insures against fire, or damage from fire, or any extraneous causes of damage outside of accident.

The one great competitor of the above-mentioned trio is the Law Accident Insurance Company, of London. This company is not in the rate combination, and its premium rates are generally only about one-half those given hereafter.

The official premium rates for dynamos, motors and gas engines charged by the three companies above are given in the appended lists.

Incidentally, it may be mentioned that there is an extensive and profitable field, if properly organized and conducted, for an enterprising American company to enter the field, for the reason that there are many thousands of users of electrical plants at the present time uninsured, who are anxious to insure, but who will not pay the apparently unreasonably high premiums at present demanded by insurance companies.

A matter of some moment to the insured when a dynamo or motor breaks down, is the long period taken before the repair work has been executed, returned and set to work, and especially is this the case in reference to rewinding burnt-out armature coils, for the insurance company takes full charge of the repairs and, as a rule, will not allow the client to have any say in the matter of repair, as to whom or where it shall be sent. It must be understood that the insurance companies have many repair firms on their list, and they send the damaged plant wherever they like, for they do not execute the work themselves. This latter circumstance suggests very forcibly that an enterprising insurance company could locate and establish a repair shop of its own, hire its own men and do its own work at probably less cost, and in much less time than the present insurance companies can get it done for.

There is undoubtedly a prospective profitable field amongst municipal electric light and power corporations, who are hiring out motors to consumers of their electric energy, so as to get a good day load. Some corporations have several hundreds of motors, ranging from ½ horse-power to 20-30 horse-power and upwards, at work, and they generally insure the whole of them against breakdown.

Only recently an insurance contract was signed between the Manchester Corporation Electricity department (who have many motors in use) and the British Engine & Boiler Insurance Company, of Manchester, and, on the other hand, within the past eighteen months the West Hartlepool Corporation, who had all their motors insured with the National Boiler & General Insurance Company, of Manchester, ceased to continue the insurance and allowed the policies to lapse, because they came to the conclusion that the premiums were excessive. This latter corporation's motors were a reasonably safe and profitable risk, because nearly all the motors were of small size, ranging from ¼ to 1 horse-power, and chiefly used in butchers' shops for driving sausage machines, dressmakers' shops for sewing-machines, and similar places doing only light work.

The three insurance companies mentioned at the commencement of the article are organized with a board of directors, a chief engineer, who also acts as general manager, a consulting department with a head engineer, assistant engineers and draughtsmen, and an agency department (the commercial or business-getting department), at the head of which is the secretary of the company, who also acts as treasurer and paymaster. The insurance department worked in conjunction with the agency department; the inspection department, with a responsible head, who organizes the inspection work, and a "reco" department, dealing with the report records, worked in conjunction with the inspection department. There is a boiler department, whose responsible head and assistant engineers deal with the boiler inspectors' reports on boiler examinations; an engine department,

whose responsible head and assistant engineers deal with engine breakdowns and inspectors' reports of examinations, and an electrical department, whose chief electrician and assistants deal with breakdowns of electrical machinery and with the outside electrical inspectors' reports on the examination of electrical plants. There is a general typewriting department, in which all the reports to be sent away are written.

All the heads of the several departments are held responsible to the chief engineer of the company for the efficient carrying on of their department.

The outside agents are remunerated upon a salary and commission basis and, in addition, are allowed legitimate expenses. They are supposed not to have any technical knowledge of the practical side of the business, i. e., in regard to hazardous risk or the suitability of the apparatus for insurance, or otherwise. They hunt up a prospective client and, if he is favourably inclined, obtain a signed proposal form at a specified quoted premium, based upon the size and type of the apparatus, and the premium quoted is determined by the keenness of competition for business.

On referring to the appended "rate tariffs," it will be noted there are classes A, B and C premiums for the same amount to be insured. These classes are not based upon the degree of risk, but depend largely upon business competition.

After the proposal form is filled up and duly signed by the prospective insurer, it is immediately sent to the head office, and the apparatus or appliance is subjected to a first inspection by a member of the companies' experienced staff of engineers.

The electrical inspector or surveyor should be a thoroughly experienced and competent engineer, with good technical qualifications, some commercial experience, tact in the handling of clients, and a very essential qualification is the using of sound judgment in reference to the suitability or non-suitability of apparatus for acceptance or rejection by the company. The breakdowns from accident are so frequent that nothing but a first-class risk should be recommended to head office for acceptance.

The first inspections are the most important duties that the inspector has to undertake, for it is on his sound judgment and ability and his recommendation that the company acts. He should recommend only first-class risks and, at the same time, should be very careful not to refuse business for the company. Many unprofitable clients and very hazardous risks have been recommended and accepted by the companies by giving too much consideration towards the latter element, and the most prudent and safest policy an inspector can adopt is to recommend no machinery or plant to head office for acceptance that he would not personally accept as a safe risk. Then if the company is doubtful about refusing the business, it can send another inspector and accept or refuse the risk as it chooses.

First inspections are very important and, in addition to judging the suitability of the risk, the inspector has to take what is called first inspection particulars. This consists in executing rough sketches in a note-book, including plan, elevation and side views of the machine foundation, location of machine in the building, method of securing machine to foundation, sketches of armature, field magnets, brush gear, brushes, insulating rings and many over-all and detail dimensions of the machine and accessories, size of bedplate foundation, slide rails, bolts (used in construction and fixing), diameter and length of armature and commutator, size of armature shaft, size of commutator wires, how wound, binding wires, number and sizes of other parts, number of commutator segments, radial depth of same, field magnet particulars, thickness of insulation, etc.

In addition, particulars are required of type of machine, maker's name and number, date of make, capacity, number of revolutions, how driven, what kind of work it is doing, etc. Diagrams of connections and particulars of accessories and fuse wires, etc.

After these particulars are obtained they have to be drafted out and recorded in ink on a four-page sketch sheet of squared, non-destructible parchment paper. This is the company's permanent record of the machine for reference and recognition, and this is kept at head office. The companies are very particular as regards the size of fuse wires they allow for certain sizes of machines, and from a very extensive and valuable experience they strongly recommend copper as the material to be used.

In addition to first inspections, the inspector has to make periodical examinations of insured electrical plant, which occur three times a year, and are for the purpose of seeing what condition it is in. In these superficial inspections there are many points of vital moment to be looked at, such as sizes of fuse wires, condition of commutators, brushes, brush gear, etc., the presence of oil, dust or grease, the insulation in general, condition of bearings, controlling switches, accessories, etc. These inspections save the companies paying for many breakdowns of a more or less expensive nature, for developing faults are frequently discovered which, if left unattended to or neglected, would sooner or later lead to breakdowns of more or less serious moment.

The greatest enemy of dynamos, motors and kindred apparatus is the accumulation of oil, grease and dust, for, if not removed, it eventually eats through and rots the insulation of the vital parts of the machine, leading to short-circuits, fusing of conductors, burn-outs, etc., which necessitate rewinding, an expensive job.

The chief points to look for in a periodical inspection are: freedom from sparking of commutator; condition of commutator surface and brushes; a close examination of the segment lugs to see if there are any loose connections where conductors are connected to lugs; bearings for wear; if oil cups are kept well filled; if field magnet coils and armature are free from copper or carbon dust, dirt, oil, or grease, and if generally in a clean condition. Loose connections, terminals and bolts should be looked for, as also freedom from excessive vibration, and particular attention must be paid to see that the "clearance" between the field magnets and revolving armature is sufficient and satisfactory. Armatures should be examined to see if they run truly in pole pieces, so that no knocking can take place between pole pieces and armature. Binding wires on the armature should be carefully scrutinized for evidence of rubbing or wearing away, and many other incidental but important points.

If the machine feels fairly hot to the touch of the hand, a temperature rise test is advisable (that is, temperature of field magnets and armature), also voltmeter and ammeter readings taken, to see if the machine is overloaded. Fuses are examined and measured (by wire gauge), and the nature of drive, that is, belts, spur gear or ropes, are examined, likewise all accessories, such as switches, controllers, wiring, etc., to see if in good and efficient condition and working order.

A report is forwarded to the head office as regards the general condition of machines or plant, any special points of neglect or weakness being recorded, so that the chief engineer can enumerate them in his report to the client, with suggestions and methods of immediate remedying thereof. The machine should be thoroughly examined when both at work and at rest.

Another important and responsible feature of the inspector's duties is the immediate visiting of firms where a

breakdown has occurred. The damage, cause thereof, etc., are carefully inquired into and, if it is a legitimate breakdown, the inspector recommends head office to accept liability, and the repair is put in hand at earliest convenience.

If it is a rewinding job (say, on armature or field magnets), the firm who is doing it is visited several times during the repair to see to its satisfactory progress. When machines are located in damp places an insulation resistance test of the armature and field magnets is, or should be, annually conducted.

These companies do considerable consulting work, advising on power, lighting and equipment schemes, specifications for machines, supervision and testing of materials, etc., and one of the duties of the inspector is to visit manufacturing firms to supervise machines under construction, examine materials used and measure sizes of parts to see if they conform to the specification requirements, and generally see if the assembling and workmanship are of a high order, and, after completion, to make a final visit and be present at the test when machine is on the test bed. Efficiency, brake-horse-power and temperature-rise tests on full-load run for several hours are stipulated and carried out.

It is needless to say that there are risks of a more or less hazardous nature, depending upon the kind of work done by machine, load on machine, location and freedom or otherwise from extraneous detrimental surroundings, and the more or less expert and experienced care under whose charge they are placed. The margin of power between what the machine is being worked at and what it is capable of doing also demand consideration, also whether the work is intermittent or continuous for several hours at a stretch. A machine that is working at its full capacity for several hours continuously is always of a risky nature, especially if the machine gets overheated.

A few instances of what are good and hazardous risks may be of value. Very safe risks are those appertaining to public-supply central stations and power plants controlled by municipal and private electrical enterprises, for the machines are well attended to, kept clean, and continuous expert attendance prevails, all these favourable conditions minimizing the risk of breakdown. Such machines are rarely overloaded, a spare plant being generally available, and as the load increases more machines are added. Then, again, in cases of emergency, developing trouble is quickly seen to, located, and the machines generally stopped or switched out of circuit before serious breakdown occurs, and such machinery is usually well protected against overloading by fuses, automatic cut-outs, etc., and also provided with voltmeters, ammeters, etc., to indicate at what load capacity they are working. Other safe risks are those in connection with motors let out on hire, for they are frequently inspected by the lighting or power authorities' inspectors, who see to their general efficient condition. Electrical plants in public institutions, such as workhouses, asylums, hospitals and public buildings, are a fairly safe risk, due to the experienced attendance they get. Motors that do light work in clean, dry locations are a safe risk.

Hazardous risks are those in which motors are located in damp places, tending to induce breakdown by leakage and insulation faults, such locations being down pits where pumping motors are installed, sometimes several thousand yards from the pit shaft, and frequently where running water exists. Such machines are only seldom looked to and thoroughly cleaned by the colliery electricians, for collieries are generally short-handed as regards experienced attendance.

A very hazardous risk is that in reference to motors used in collieries

for special work, and located close to shakers, screens, nut belts, etc., which places are full of fine coal dust while work is in operation. It is practically impossible to prevent the grit and dust finding its way into the armature windings and core slots, where it grinds in and damages the insulation, causing short-circuits between the conductor windings and core plates, with resulting burn-outs, necessitating rewinding—a usually expensive job. More particularly is this the case with reference to three-phase and polyphase motors. The "clearance" or "air gap" between "rotor" and "stator" is very small, something like one-thirty-second of an inch, and the gritting coal dust finds its way into the interstices of the windings with detrimental results. In such locations and with machines of this type, in nine cases out of ten the breakdown consists of short-circuits between the core plates and windings either of the "stator" or "rotor," due to grinding in of dust and grit by the revolving "rotor." These are very hazardous risks, not only on account of the disadvantageous conditions under which they work, due to location, but also owing to the fact that when such breakdowns occur they are such expensive ones to repair, nothing being so costly as rewinding jobs. Motors located in steel works are hazardous, especially those located in grinding shops, where grit and dust abound. Motors that drive metal cutting shears are subjected to variable power demands and are somewhat liable to breakdown, as likewise are motors used to drive coal elevators or conveyors, especially if they are started up under load, and similarly for the same reason motors used to drive grain elevators in malting establishments are somewhat risky, likewise are crane motors, especially those used in timber yards for lifting and transporting heavy timber about the yards. Motors used in sawmills are liable to breakdown, owing to the frequent excessive overloading when sawing big timbers, and the fuses are indiscriminately changed and made larger by the sawmill man, generally not an experienced electrician, the fuse thus affording no adequate protection of the motor. Machines are always of a more or less risky nature when under the charge of men who are not experienced electricians (so-called handy men, who have a variety of jobs to do). This is due to their ignorance from two standpoints; firstly, they do not, or will not, realize the great importance of absolute cleanliness; and secondly, they will indiscriminately overload the machines when occasion demands. This "handy-man caretaker" condition is very prevalent in establishments where there are only two or three motors, and when it does not pay to employ an electrician, and this condition exists generally in sawmills.

A study of surrounding conditions, as regards location of machines, class of work done, and whether attendant is experienced or otherwise, will generally give a sound basis on which to judge the suitability for insurance and more or less hazardous nature of risk, and this very forcibly suggests and points out that the logical and sound commercial basis upon which to organize and administer an accident insurance business of this kind is by apportioning the premium or rate tariff according to hazard or degree of risk of the machinery or plant under consideration, instead of quoting one set premium for a certain size of machine, irrespective of its working conditions, such as is now adopted by the British companies.

That insurance against breakdown in Great Britain is a profitable venture is amply illustrated by the fact that the National Boiler & General Insurance Company, of Manchester, has for the past few years made a sufficiently handsome profit to pay an annual dividend of approximately 30 per cent., and the other two companies mentioned also make handsome profits.

Rates for Dynamos

Premium for a single dynamo or alternator. When there is more than one machine to be insured, the premium for each machine after the first to be reduced by five shillings. To calculate kilowatts, multiply amperes by volts and divide by 1,000. The result is kilowatts.

K W.	Class.				Class.				Class.			
	A	B	C	Amount	A	B	C	Amount	A	B	C	Amount
	£ s d	£ s d	£ s d	£	£ s d	£ s d	£ s d	£	£ s d	£ s d	£ s d	£
1	1 0 0	1 2 0	1 4 0	10	. . .	. . .	. . .	..	1 3 6	1 8 6	1 11 0	20
2	1 1 0	1 3 0	1 5 0	15	. . .	. . .	. . .	..	1 7 3	1 10 0	1 12 9	30
3	1 2 0	1 4 3	1 6 6	15	. . .	. . .	. . .	..	1 8 6	1 11 0	1 14 0	30
4	1 3 0	1 5 3	1 7 6	15	. . .	. . .	. . .	..	1 10 0	1 13 0	1 16 0	30
5	1 4 0	1 6 6	1 9 0	20	. . .	. . .	. . .	..	1 11 6	1 14 6	1 17 6	40
6	1 6 0	1 8 6	1 11 0	20	1 11 9	1 15 0	1 18 3	30	1 14 0	1 17 6	2 1 0	40
7	1 8 0	1 10 9	1 13 6	25	1 14 0	1 17 6	2 1 0	35	1 16 6	2 0 0	2 3 6	50
8	1 10 0	1 13 0	1 16 0	25	1 16 3	2 0 0	2 3 6	35	1 19 0	2 3 0	2 7 0	50
9	1 12 0	1 15 3	1 18 6	25	1 18 6	2 2 6	2 6 0	35	2 1 6	2 5 6	2 9 6	50
10	1 14 0	1 17 6	2 1 0	30	2 0 9	2 4 9	2 8 9	45	2 4 0	2 8 6	2 13 0	60
12	1 16 6	2 0 0	2 4 0	30	2 4 3	2 8 6	2 13 0	45	2 7 6	2 12 3	2 17 0	60
14	1 19 0	2 3 0	2 7 0	30	2 7 9	2 12 6	2 17 3	45	2 11 0	2 16 0	3 1 0	60
16	2 1 6	2 5 6	2 9 6	40	2 11 3	2 16 6	3 1 6	60	2 14 6	3 0 0	3 5 6	80
18	2 4 0	2 8 6	2 13 0	40	2 14 9	3 0 3	3 5 9	60	2 18 0	3 3 9	3 9 6	80
20	2 6 6	2 11 0	2 15 6	50	2 18 3	3 4 0	3 9 9	75	3 1 6	3 7 6	3 13 6	100
25	2 11 6	2 16 6	3 1 6	50	3 4 6	3 11 0	3 17 6	75	3 7 6	3 14 0	4 1 0	100
30	2 16 6	3 2 0	3 7 6	50	3 10 9	3 17 9	4 4 9	75	3 13 0	4 0 0	4 7 6	100
35	3 1 6	3 7 6	3 13 6	60	3 17 0	4 4 9	4 12 6	90	3 19 0	4 7 0	4 15 0	120
40	3 6 6	3 13 0	3 19 6	60	4 3 3	4 11 6	4 19 6	90	4 6 6	4 15 0	5 3 9	120
45	3 11 6	3 18 6	4 5 6	75	4 8 3	4 17 3	5 6 0	110	4 11 6	5 0 0	5 9 6	150
50	3 16 6	4 4 0	4 11 6	75	4 13 3	5 2 6	5 11 9	110	4 16 6	5 6 0	5 15 6	150
55	4 0 6	4 8 6	4 16 6	75	4 18 3	5 8 0	5 18 0	110	5 1 6	5 11 6	6 1 6	150
60	4 4 6	4 13 0	5 1 6	100	5 3 3	5 13 6	6 3 9	150	5 6 6	5 17 0	6 7 6	200
65	4 8 6	4 17 3	5 6 0	100	5 7 0	5 17 9	6 8 6	150	5 11 6	6 2 6	6 13 6	200
70	4 12 6	5 1 9	5 11 0	100	5 10 9	6 2 0	6 13 0	150	5 16 6	6 8 0	6 19 6	200
75	4 16 0	5 5 6	5 15 0	125	5 14 6	6 6 0	6 17 6	185	6 1 6	6 13 6	7 5 6	250
80	4 19 6	5 9 6	5 19 6	125	5 18 3	6 10 0	7 2 0	185	6 6 6	6 19 0	7 11 6	250
85	5 3 0	5 13 3	6 3 6	125	6 2 0	6 14 0	7 6 0	185	6 11 6	7 4 6	7 17 6	250
90	5 6 6	5 17 0	6 7 6	150	6 5 9	6 18 0	7 10 6	225	6 16 6	7 10 0	8 3 6	300
95	5 9 6	6 0 6	6 11 6	150	6 9 6	7 2 6	7 15 6	225	7 1 6	7 15 6	8 9 6	300
100	5 12 6	6 3 9	6 15 0	150	6 13 3	7 6 6	7 19 9	225	7 6 6	8 1 0	8 15 6	300

Rates for Motors

Premium for a single continuous current or alternating current motor to include insurance of starting switch. When it is desired to insure a motor without the starting switch, the above rates should be reduced by 15 per cent. = three shillings per pound. When there is more than one machine to be insured, the premium for each machine after the first to be reduced by five shillings.

H.P.	Class.				Class.				Class.			
	A	B	C	Amount	A	B	C	Amount	A	B	C	Amount
	£ s d	£ s d	£ s d	£	£ s d	£ s d	£ s d	£	£ s d	£ s d	£ s d	£
¼	1 1 0	1 3 0	1 5 0	5	. . .	. . .	. . .	..	1 3 0	1 10 0	1 12 6	10
½	1 2 0	1 4 3	1 6 6	10	. . .	. . .	. . .	..	1 8 6	1 11 3	1 14 0	20
1	1 3 3	1 5 6	1 7 9	10	. . .	. . .	. . .	..	1 10 0	1 13 0	1 16 0	20
2	1 4 6	1 7 0	1 9 6	15	. . .	. . .	. . .	..	1 12 0	1 15 0	1 18 6	30
3	1 6 0	1 8 6	1 11 0	15	. . .	. . .	. . .	..	1 14 0	1 17 6	2 1 0	30
4	1 7 6	1 10 0	1 13 0	15	. . .	. . .	. . .	..	1 16 0	1 19 6	2 3 0	30
5	1 9 3	1 12 0	1 15 0	20	1 14 0	1 17 6	2 1 0	30	1 18 6	2 2 3	2 6 0	40
6	1 11 0	1 14 0	1 17 0	20	1 16 6	2 0 0	2 3 6	30	2 1 0	2 5 0	2 9 0	40
7	1 13 0	1 16 3	1 19 6	25	1 19 0	2 3 0	2 7 0	35	2 3 6	2 8 0	2 12 6	50
8	1 15 0	1 18 6	2 2 0	25	2 1 6	2 5 6	2 9 0	35	2 6 0	2 10 6	2 15 0	50
9	1 17 0	2 0 6	2 4 0	25	2 4 0	2 8 6	2 13 0	35	2 8 6	2 13 0	2 17 6	50
10	1 19 0	2 3 0	2 7 0	30	2 6 6	2 11 0	2 15 6	45	2 11 0	2 16 0	3 1 0	60
12	2 2 0	2 6 3	2 10 0	30	2 10 0	2 15 0	3 0 0	45	2 14 6	3 0 0	3 5 6	60
14	2 5 0	2 9 6	2 14 0	30	2 13 6	2 18 9	3 4 0	45	2 18 0	3 3 9	3 9 0	60
16	2 8 0	2 12 9	2 17 6	40	2 17 0	3 2 9	3 8 6	60	3 1 6	3 7 6	3 13 6	80
18	2 11 0	2 16 0	3 1 0	40	3 0 6	3 6 6	3 12 6	60	3 5 0	3 11 6	3 18 0	80
20	2 14 0	2 19 6	3 5 0	50	3 4 0	3 10 6	3 17 0	75	3 8 6	3 15 0	4 2 0	100
25	2 19 0	3 5 0	3 11 0	50	3 10 3	3 17 0	4 4 0	75	3 16 0	4 3 6	4 11 0	100
30	3 4 0	3 10 3	3 16 6	50	3 16 6	4 4 0	4 11 6	75	4 3 6	4 11 9	5 0 0	100
35	3 9 0	3 16 0	4 3 0	60	4 2 9	4 11 0	4 19 6	90	4 11 0	5 0 0	5 9 0	125
40	3 14 0	4 1 6	4 9 0	60	4 9 0	4 18 0	5 7 0	90	4 18 6	5 8 0	5 18 0	125
45	3 17 9	4 5 6	4 13 0	75	4 14 0	5 3 6	5 13 0	110	5 3 6	5 13 9	6 4 0	150
50	4 1 6	4 9 6	4 17 6	75	4 19 0	5 9 0	5 19 0	110	5 8 6	5 19 0	6 10 0	150
55	4 5 3	4 13 9	5 2 3	75	5 4 0	5 14 6	6 5 0	110	5 13 6	6 4 9	6 15 0	150
60	4 9 0	4 18 0	5 7 0	100	5 9 0	6 0 0	6 11 0	150	5 18 6	6 10 0	7 2 0	200
65	4 12 9	5 2 0	5 11 0	100	5 12 9	6 3 9	6 15 0	150	6 3 6	6 15 6	7 7 6	200
70	4 16 6	5 6 0	5 15 6	100	5 16 6	6 8 0	6 19 6	150	6 8 6	7 1 0	7 14 0	200
75	5 0 3	5 10 0	6 0 0	125	6 0 3	6 12 3	7 4 3	185	6 13 6	7 6 9	8 0 0	250
80	5 4 0	5 14 3	6 4 0	125	6 4 0	6 16 6	7 9 0	185	6 18 6	7 12 6	8 6 6	250
85	5 7 9	5 18 6	6 9 0	125	6 7 9	7 0 6	7 13 0	185	7 2 3	7 16 6	8 10 6	250
90	5 11 6	6 2 6	6 13 6	150	6 11 6	7 4 6	7 17 6	225	7 6 0	8 1 0	8 15 6	300
95	5 15 3	6 6 6	6 18 0	150	6 15 3	7 8 6	8 2 0	225	7 9 9	8 5 0	9 0 0	300
100	5 19 0	6 11 0	7 3 0	150	6 19 0	7 13 0	8 7 0	225	7 13 6	8 8 6	9 3 6	300

Gas Engine Rates—for Belt or Rope Driving

Nominal Horse-power	Diameter of Cylinder.	Class A.				Class B.				Class C.			
		£50	£100	£200	£300	£50	£100	£200	£300	£50	£100	£200	£300
	Ins.	£ s d	£ s d	£ s d	£ s d	£ s d	£ s d	£ s d	£ s d	£ s d	£ s d	£ s d	£ s d
1½	4	1 0 0	1 5 0	. . .	. . .	1 2 0	1 7 6	. . .	. . .	1 4 0	1 10 0	. . .	. . .
2½	5	1 2 6	1 10 0	. . .	. . .	1 4 9	1 13 0	. . .	. . .	1 7 0	1 16 0	. . .	. . .
3½	6	1 5 0	1 15 0	2 0 0	2 4 0	1 7 6	1 18 6	2 4 0	2 8 4	1 10 0	2 2 0	2 8 0	2 12 10
5	7	1 10 0	2 2 0	2 7 0	2 11 0	1 13 0	2 6 2	2 11 8	2 16 1	1 16 0	2 10 4	2 16 5	3 1 2
6	8	1 15 0	2 9 0	2 14 0	2 18 0	1 18 6	2 13 10	2 19 4	3 3 9	2 2 0	2 18 9	3 4 10	3 9 7
8	9	2 0 0	2 16 0	3 2 0	3 6 9	2 4 0	3 1 7	3 8 2	3 13 5	2 8 0	3 7 2	3 14 5	4 0 0
10	10	2 5 0	3 3 0	3 10 0	3 15 6	2 9 6	3 9 3	3 17 0	4 3 0	2 14 0	3 15 7	4 4 0	4 10 7
12	11	. . .	3 10 0	3 18 0	4 4 3	. . .	3 17 0	4 5 9	4 12 6	. . .	4 4 0	4 13 7	5 1 0
14	12	. . .	3 17 0	4 7 0	4 15 0	. . .	4 4 8	4 15 8	5 4 6	. . .	4 12 5	5 4 4	5 14 0
16	13	. . .	4 4 0	4 16 0	5 6 0	. . .	4 12 4	5 5 7	5 16 6	. . .	5 0 9	5 15 2	6 7 3
20	14	. . .	4 12 0	5 7 0	5 19 0	. . .	5 1 2	5 17 8	6 11 0	. . .	5 10 5	6 8 5	7 2 9
22	15	. . .	5 0 0	5 17 0	6 11 0	. . .	5 10 0	6 8 8	7 4 0	. . .	6 0 0	7 0 5	7 17 3
25	16	. . .	5 8 0	6 8 0	7 4 0	. . .	5 18 9	7 0 10	7 18 4	. . .	6 9 7	7 13 7	8 12 9
28	17	. . .	5 17 0	7 2 0	8 0 0	. . .	6 8 8	7 16 2	8 16 0	. . .	7 0 5	8 10 5	9 12 3
32	18	. . .	6 6 0	7 16 0	8 16 0	. . .	6 18 7	8 11 7	9 13 6	. . .	7 11 2	9 7 2	10 11 0
36	19	. . .	6 15 0	8 5 0	9 7 0	. . .	7 8 6	9 1 6	10 5 6	. . .	8 2 0	9 18 0	11 4 6
40	20	. . .	7 5 0	9 0 0	10 5 0	. . .	7 19 6	9 18 0	11 5 6	. . .	8 14 0	10 16 0	12 6 0

Quote by cylinder size—not by nominal horse-power. The particulars given of nominal horse-power are for general information, and are approximate only.

The above rates to be increased by 10 per cent. if the engines drive by spur gear.

THE GASOLINE MOTOR IN FARM DEVELOPMENT

By George Ethelbert Walsh

AS the telephone revolutionized farming conditions in the United States a dozen years ago, and as the suburban electric railway has made life in the rural districts more satisfying in recent times, so the gasoline motor is rapidly assuming a potential and actual possibility in changing farm life and developments. American farmers have always been the greatest users of machinery of any nation of the world, and American farm implements and machines, stimulated in the manufacture by the incessant home demand, have to-day invaded the markets of the civilized globe. In prosperous seasons and in years of adversity the American farmer buys and uses machinery that would cause expressions of astonishment from the agriculturists of any other country. But it is not extravagance that influences him in this; it is hardly a luxury to own a modern reaper and binder, a combined seeder and planter, or a traction plow and harrow. It is a necessity of the age to employ machinery in every conceivable form to harvest the gigantic crops. Without such aids to agriculture, the annual harvest of the country would be cut down more than 50 per cent.

The advent of the gasoline motor in farming life has come in the interests of economy, efficiency and, possibly, for the sake of the luxury which it brings. That it has become within a few brief years a potent factor in American agriculture is an assurance of its need. With the appearance of the automobile on the streets of the towns and cities, the prediction was made that the horseless age was approaching—except on the farms. The last census showed, however, that the horseless age was still far off, and the number of these useful animals was greater in 1906 than ever before in the history of the country. But for farm work, as well as for heavy trucking in towns and cities, the horse is becoming less and less a necessary beast of burden. If we can accept the statistics of farm implement manufacturers, the great traction engines of the Western wheat farms, and the smaller gasoline engines of the East and West, have displaced upward of 200,000 horses in planting and harvesting crops.

The heavy steam traction engine has been in service for upward of a quarter of a century in the West, and it has given great stimulus to farming on a large scale. It displaces from fifty to one hundred horses, hauling freight to market and operating gangs of twenty and more plows. It has driven threshing machines, propelled reapers and binders across miles of rich wheat land, and harvested crops in a few weeks which would require the services of hundreds of men and horses. The big wheat farmer found his salvation in the big tractors of American invention.

Now the more efficient gasoline engine has come into the field. The farmer who could not afford a 50 horse-power steam engine, and could not make it profitable if he had it on his restricted acreage, finds, in the smaller gasoline engine, a cheap, efficient and profitable substitute. In stationary and portable outfits the new power machine performs its work satisfactorily. It plows his

fields, plants his grain, cuts and harvests the crops, and hauls the products to market. It revolves the churn for the dairyman, drives the separator for the creamery men, generates electricity for home and barn lighting, shears the sheep of the big sheepmen, clips the horses for the stock raiser, and lightens the burden of the housewife by pumping water, running sewing machines and washing outfits. The heavy steam traction engines were used chiefly for threshing and reaping on the big farms; but the little, powerful gasoline motor is so flexible that it is in use for a dozen little jobs that were formerly done by hand or horse-power. The traction engines opened up to cultivation the great tract of rich farming lands extending from the Hudson Bay to the Gulf of Mexico, and from the Mississippi to the Rockies, which, on account of the scarcity of men and teams, could not formerly be tilled; but the gasoline motor has divided and sub-divided this empire of fertility into thousands of farms, which the ordinary farmer now cultivates. It has accomplished for the small farm what the steam tractor did for the thousand-acre farms.

The gas engine has become the farmer's "reliable" in arid regions where scarcity of water makes steam power impracticable. It pumps the water for house use and for irrigation, saws and cuts the wood, and even carries the farmer and his family to town on pleasure or business. Motor cars are not considered luxuries for farmers, but recent developments indicate that the modern automobile is not for the city man alone. The farmer has become a pretty good buyer of motor cars in many sections. Farmers buying touring cars may seem a novelty to some, but in Illinois it is not an unusual occurrence. In the past twelve months forty touring cars, averaging $1,250 each, were sold to farmers in one county in Illinois. More than one agency, according to an automobile authority, sold more cars during 1907 in Chicago to farmers than to town and city people, and they are just beginning to develop the trade. And this in a State not noted for its beautiful country roads! The conclusion is that farmers are coming to believe that there is both utility and pleasure in a motor car. It does the duty of half a dozen horses, and gives pleasure while it makes profit for the owner.

It was a short step from the portable gasoline engine to the motor car. Full credit has not been given to the farmers for the knowledge of the new power. The city man, flushed by the pride of owning a new toy which he can manipulate, finds it somewhat difficult to believe that the farmer knows more about the mechanism of his machine than he does himself. Many a motor enthusiast, when stranded by the wayside, has found that the man in the blue jeans and wide-brimmed straw could locate the trouble of his machine and repair it as well as an expert mechanic. Why? Because years of close association with stationary and portable gasoline engines has acquainted him with the simple mechanism of this type of power-producer. The automobile may have more parts and intricacy of machinery than the ordinary farm engine, but the general principles hold the same. The farmer is not able to run to a repair shop every time something goes wrong with his engine, and self-reliance has taught him many things that the city man does not know.

The flexibility of the small portable gas engine is one of its remarkable attributes. As an illustration, a farmer who owns a 10 horse-power portable gas engine put it to divers uses of an unusual nature. The engine, mounted on four wheels, propelled itself from place to place by means of a driving gear. When in the field it was harnessed to a corn-stalk cutter by means of a belt, and later, when run to the barn, it drove

a large threshing and winnowing machine. In dry weather it pumped water for irrigation, filling the reservoirs and ditches rapidly. In the fall it was taken to the wood pile, where it worked a circular saw and cut up the season's supply of fuel. It was harnessed with equal ease to a bone-cutter, a feed-cutter, a grindstone, a cream separator and a mammoth churn. It could have been installed in the barn in the winter to generate electricity for lighting the home, but the owner did not have a dynamo plant on his premises.

The farmer is now looking forward to the development of cheap, denatured alcohol for fuel, and, if this dream is once achieved, he will be as independent as any city man. From his potatoes, beets and corn-stalks he will produce his own fuel, using his gasoline motor for the operation. The changes required in the engine to burn alcohol are very slight, and many of the manufacturers are aiming to place on the market machines which will use either fuel. With the increasing advance in the price of gasoline, the farmer naturally anticipates the production of the new systems of distilling alcohol from farm products that are to-day little more than waste to him. His old, reliable engine then will make the cycle of operation complete—plowing and harrowing the soil, planting the seed, cultivating the plants, harvesting and threshing the crop and, finally, converting the waste into fuel alcohol for burning in the motor.

The saving effected by the modern powerful gasoline engine on the farm is estimated from 20 to 50 per cent. over horse, man or steam power. When not running, the engine is not consuming fuel, and its keep through the winter when in storage is nothing. It does not eat its head off, and its compactness makes storage space required for it very little. Manufacturers have made special lines of farm engines in various sizes, ranging from 5 to 100 horse-power, both for stationary work and portable use. Upward of fifty thousand such engines have been sold to American farmers in the past two years, and the demand for the present year will exceed any past record. Some of these are remarkable adaptations to particular needs. Such a gasoline farm engine is adapted for dragging heavy gangs of plows across long fields, followed by harrows, cultivators, seeders and harvesters. In fact, the land can be tilled, planted and the crops harvested with a machine of this sort without the aid of a single horse, and with very little hired help. The farmer thus becomes a more independent unit than ever before.

In the great Northwest the portable gasoline threshing outfits are conspicuous features at the harvest season. They are much lighter than the old steam threshing plants, and they are self-propelling, on rubber tires, so that they can be run easily and quickly from farm to farm. Some of these complete outfits are designed to travel at the rate of six to seven miles an hour. The designers of the new portable gasoline threshing machines have been in the field studying the needs of the farmers, and it is now common to find every three or four neighbouring farmers jointly owning and operating a portable threshing machine. The demand for hired help is cut down to a minimum. The farm-help problem is thus being partly solved in the great Northwest. Even in the new Northwest of Canada scores of these machines have been put in operation in the last year. The great wheat crop could not be harvested and threshed without such appliances.

The gasoline motor, as an economical machine, is no less important in marketing products, and it promises to figure conspicuously in the agricultural life of the near future. The modern touring cars and runabouts sold to farmers are for utility first and pleasure after-

ward. One owner of a touring car in La Salle County, Illinois—which, by the way, is one of the ten counties of the country which have the greatest crop yield, yielding last year $7,201,557 worth of produce—stripped the machine of tonneau and all fancy rigs and put it into commercial service in a most profitable manner. With a huge, box-like arrangement on the back, he managed to carry big loads of perishable articles to market, ten miles away. With a rural telephone in his house, he kept in touch with prices for commodities, and when rates advanced for a day he rushed poultry, fresh fruits, eggs, butter and fresh vegetables to the city. His account-book showed that he realized $300 more in one season for his articles than if he had sold them in the old way, taking the market prices as they varied from day to day. Another farmer having a lot of fancy poultry made in one trip $75 more than the regular profits through rushing a load to market during a day of high prices.

The farmers' wives and daughters have learned to operate the machines, and it is not unusual to see them peddling farm produce from automobiles in many of the Western towns and cities. Some of them run in from ten to twenty miles and sell their produce before noon and get back again in the early afternoon. The trip to the town is a pleasurable occupation, and the hard-worked wife finds it both profitable and pleasurable to turn to this interesting work.

Nor should the social effects of the motor car be overlooked in farm life. In the Northwest, where the distance between farms averages five to ten miles, the monotony of existence becomes frequently almost intolerable. It was a tiresome trip to visit neighbours often with horse power, and neighbours would sometimes see each other only a few times in the course of a year. The farmer, with his automobile, has brought his neighbours close to him. A ten or twenty-mile jaunt for a social visit in the morning is a pleasure in a motor-car, even if the roads are not especially good. The housewife thus visits her neighbours at least once a week, and in the dull season, after the crops are harvested, these visits frequently increase to two or three a week. Social entertainments are made possible thereby, and trips to the towns and cities for pleasure and shopping come within the range of those living ten and twenty miles away.

The social effect of the automobile on American farm life is thus as important, in a way, as the business side. Manufacturers of motor cars adapted to the prairie districts are assiduously cultivating this trade among farmers. Instead of looking upon them as enemies of the automobile and of motor enthusiasts, they realize that they will prove, in the near future, their best patrons. Fancy, high-priced cars are not designed for them, but practical, powerful and strong machines which will stand the rough roads of the farming country are in demand. Where the roads are good the farmer's motor car is more in evidence than in other regions, but nearly every prosperous section has them, and the demand for better roads begins with the farmer at his home.

THE NEW STONE BRIDGE OVER THE CONNECTICUT RIVER AT HARTFORD

By E. W. Winans

AN ARCH OF THE HARTFORD BRIDGE

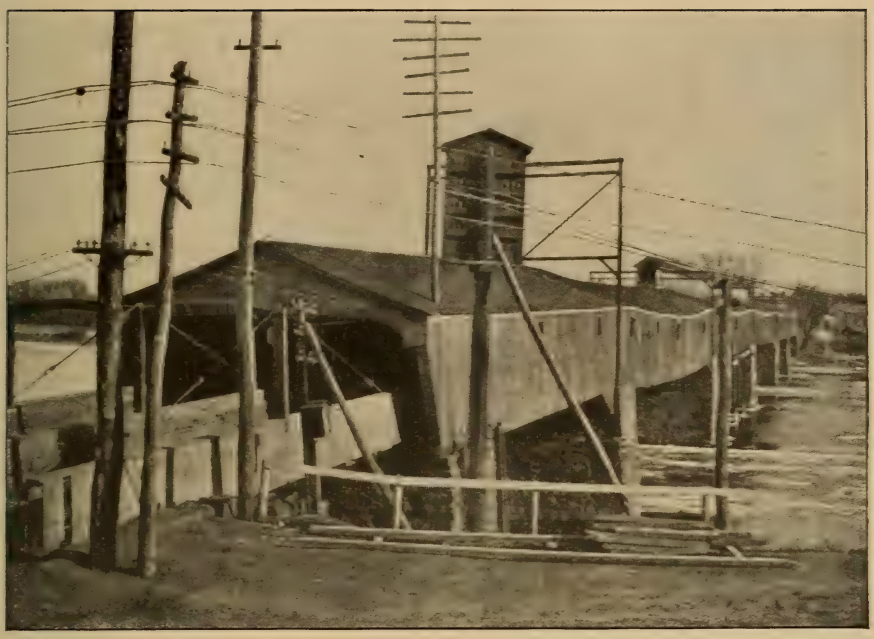
THE last stone has been laid in the construction of a stone bridge which is destined to take rank as one of the greatest of its kind in the world. The bridge, with its approaches, took nearly three years to build, and cost about three million dollars. It is composed of nine spans, having maximum dimensions of a reach of 119 feet and a clear height of arch of 45 feet, is 82 feet wide, and has a total length of 1,192.5 feet.

The famous London Bridge, which has hitherto ranked first among stone bridges, is but 62 feet wide, 1,005 feet long, and has five arches, with a longest span of 152 feet and a maximum rise of arch of 27.5 feet.

This Connecticut bridge is not remarkable for its length of span, for there are several stone bridges with a span of over 200 feet; but these are generally narrow, one-span structures, as, for instance, the Cabin John Creek bridge, carrying the Washington Aqueduct, which has a span of 220 feet and a width of but 20 feet. Neither is it the longest bridge, for there is the Congleton Viaduct, in England, which has forty-one arches and is 2,870 feet long and 25 feet wide. Although it is one of the widest bridges, it is not any one feature that stamps it great, but a summary of size of arch, of length and breadth, combined with its perfection of structure and symmetry of outline, that makes plain the claim of superiority.

The King's Highway was the old Colonial through route from Boston to New York and crossed the Connecticut River at Hartford. Even today it is known by the same name between Stamford and Bridgeport and from Hartford east through Tolland county, for a distance of about 30 miles, and an occasional old-fashioned inn, under a canopy of venerable elms, still serves to recall the days when the lumbering stage coach took the place of the present limited express.

During the earlier years of Hartford's history the only means of crossing the Connecticut was a ferry, but in 1810 a stock company built a toll bridge that extended only from shore to shore, and in times of high water the passengers had to be carried over the meadows of East Hartford by boat. In March, 1818, this bridge was carried away by ice, and was shortly followed by the second bridge, which was built of native upland pine on the piers of the first one, with the roadway hung over the lower chords of the trusses, which sprang from the piers 4 feet higher than formerly. The original bridge of 1810, including land rights, cost $96,000; the bridge of 1818, which stood on the old piers, cost $30,000; the causeway cost about $150,000, and the cost of maintenance of



THE OLD TOLL BRIDGE AT HARTFORD. BUILT 1818. BURNED MAY 17, 1895

bridge and causeway up to 1844—which was brought out by a suit between the bridge and the ferry companies—was $47,000. In May, 1889, the bridge was bought by the State and the neighbouring towns and made free to the public. After standing for more than seventy-five years, it burned in 1895, making one of the most spectacular displays ever seen in the Connecticut valley, and was witnessed by 20,000 people collected on the shores.

A temporary steel truss bridge, erected in June of that year, was carried away five months later by an ice jam, and was followed in May, 1896, by a second temporary bridge that was guaranteed for but five years. It was composed of nine steel truss spans, varying in length from 90 to 136 feet, and supported on pile piers planked around the outside and filled with loose "hand-dump" stone. Although the truss members are extremely light, the bridge is stiff and free from vibration, and has been described by bridge engineers as "one in which the steel has been made to act with greater efficiency than in almost any other structure." This bridge has served for eleven years, and is now closed to traffic and will soon be removed.

In 1895 the State Legislature enacted a law creating the Connecticut River Bridge and Highway District Commission, and Senator Morgan G. Bulkeley was appointed and has remained its chairman. This law provided for the issuing of bonds to raise money for the erection of a bridge and the construction of a causeway and approaches, and provided for the apportionment of the expense among five neighbouring towns directly benefited by the work. After a long and bitter controversy, an act was passed in Congress and signed by the President in 1903, permitting the building of the bridge without a draw, as it was reported by a commission from Washington that it would cost $3,000,000 to make the river navigable between Hartford and Springfield. The War Department then gave its consent.

Three estimates were presented by the Bridge Commission for a permanent bridge—$782,000 for a steel girder bridge, $878,000 for a steel arch bridge, and $1,600,000 for a stone arch bridge, with the approaches estimated at $709,000. At a meeting of various business associations and the general public, the stone bridge was unanimously chosen, and later, in April, 1902, at an election, resolutions were adopted calling for an appropriation of $1,000,000 for the bridge and $709,000 for the approaches, and later an additional issue of bonds, to the amount of $500,000, was made.

Besides the stone bridge, the improvements include, at the east end, a straight macadam boulevard approach, already completed, which is 1 mile long, and the greater portion of which is an earth-fill, 70 feet wide and with a maximum depth of fill of 30 feet, carrying the roadway over the low meadows, which are submerged in times of high water, the maximum rise recorded being 29 feet. To give relief during these times of freshet, a bridge was provided, which is composed of eight 40-foot deck plate girder spans, with a buckle plate floor and an asphalt pavement. The boulevard approach at the west end is L-shaped in plan, runs parallel to the river for 1,600 feet, turning at right angles to cross a railroad tunnel, extending 200 feet on either side to protect the bridge from smoke, and to enter the bridge. It is 90 feet wide and has a total length of 1,800 feet.

On the site of the west end boulevard there formerly stood unsightly tenements which, sixty years ago, were occupied by the best stores and residences of the city of about 10,000. Some of the old buildings had most interesting histories, among which was Asa Forwell's warehouse, built in about 1840, and used in his trade with the West Indies, housing so many casks of St. Croix or Jamaica rum that its owner was able to build the finest house in Hartford, which he paid for out of a wooden chest in silver and gold of American, French, English and Spanish coinage. Then there was the Taylor grocery store, 1835, which was a great place for the people to stop in on their way to the wharf to see the New York or Springfield boat come in, this being the only method of reaching these cities beside the slow stage coach. The line was owned by the Vanderbilts, and it was no uncommon thing for Captain Jacob Vanderbilt, of the *Water Witch*—brother of the old commodore, Cornelius Vanderbilt—to stop in for his glass of St. Croix rum with a little West Indian molasses stirred in. All these and many other buildings of more or less antiquity had to be bought and removed, and the N. Y., N. H. & H. R. R. tracks had to be moved nearer the river and lowered to pass under the raised boulevard where it turns to enter the bridge. This boulevard and the river front will be skirted by trees and flowers, forming a public park and a fitting approach to the bridge.

The bridge is crossed by two street car lines on a roadway 60 feet wide, and has a 10-foot sidewalk on either side.

The construction plant, located at the east end of the bridge and covering about three acres, consisted of a central power plant, a sawmill, planing mill, machine shop, forge and stone cutting department. The stone cutting and finishing were done in and about a great building 60 feet wide and 208 feet long, and was fitted with twenty-three pneumatic tools—each taking the place of eight men—and a 5-ton overhead girder electric crane running the entire length of the building. In an adjoining building were the planing mill and the sawmill, where the huge beams, 1 foot square and sometimes 46 feet long, were cut into shape and hauled, by means of a "Dinky" engine, down the tracks to the dock on the edge of the river, where huge cranes reached down with giant hooks

SINKING A CAISSON. THE DISCHARGE OF WATER IS CAUSED BY THE ESCAPE OF AIR FROM THE WORKING CHAMBER

and swung the beams into place for building the caissons or the false work for supporting the arches.

In the engineers' office of the plant was erected a testing plant, where samples from each lot of cement were moulded into small blocks and, to pass inspection, had to show a crushing strength of 3,000 pounds per square inch. A system of immense cranes, capable of passing a heavy block of stone from one end of the plant to the other, completed the equipment of a large industry in itself capable of giving employment to three or four hundred men at one

CONSTRUCTION OF A PIER, CAISSON SHAFTS AND CONCRETE MIXER

time. To this plant were taken the rough timbers and blocks of stone, and from it were delivered the construction timbers and finished stones that would fit into their places like bearings on a crankshaft.

The materials used in the construction of the bridge were: concrete for the foundations; Leete's Island granite, a stone of a neutral colour, for the top of the foundations to the springing line of the arches, and Stony Creek granite, a stone of a light, pinkish hue, for the arches and all of the structure above. The vital statistics of the bridge are as follows:

Total length, 1,119.5 feet. Total

THE TEMPORARY STEEL BRIDGE

width, 82 feet. Nine spans, beginning at the west or Hartford end, as follows: 101.5 feet, 108 feet, 115 feet, 119 feet, 115 feet, 108 feet, 81 feet, 74 feet, 68 feet. Rise of arch, beginning at the west end, 25.375 feet, 27 feet, 28.75 feet, 29.75 feet, 28.75 feet, 27 feet, 25.11 feet, 22.94 feet, 21.08 feet. Width of piers beginning at the west end, 13 feet, 40 feet, 18 feet, 19 feet, 19 feet, 18 feet, 40 feet, 16 feet, 15 feet. Maximum clear height to intrados of arch above low water, about 45 feet. Bridge designed for maximum load without practical limit. Clear roadway, 80 feet, divided into two 10-foot sidewalks with a 60-foot roadway between.

Foundations made by the pneumatic-caisson process.

Deepest foundation about 50 feet below ordinary low water.

Largest caisson (of which there were two of the same size), 46 feet by 131 feet, which is a single working chamber of this dimension, one of the largest ever used.

Weight of the largest finished stone used in the construction of the bridge proper, about 40 tons.

Total amount of masonry in the bridge proper, about 100,000 cubic yards.

About 125,000 barrels of cement were used in the construction of the bridge.

Cost of bridge (1,600,000) (1,359,520) dollars.

Cost of entire system, including the bridge, approaches and a steel girder bridge for the east end boulevard, about $3,000,000.

Senator Morgan G. Bulkeley, president of the Connecticut River Bridge Commissioners.

Chief engineer, Edwin D. Graves, succeeded by Deputy Chief Engineer John T. Henderson. Assistant engineer, Edward W. Bush.

Consulting engineer, Alfred P. Boller, New York.

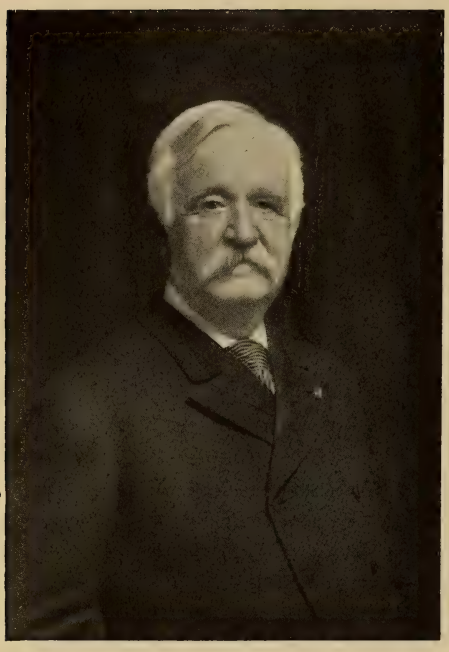
Consulting architect, Edmund M. Wheelwright, Boston, Mass.

Contractors, McMullen, Weand & McDermott, New York, N. Y.

From the bed-rock, varying from 25 to 50 feet below low water, the foundations or lower parts of the piers were constructed of solid concrete by means of pneumatic caissons, and it was this process of building under water and through sand, clay and hard pan, massive concrete blocks, about 46 feet wide, 135 feet long and 42 feet high—in the largest pier—that formed the most interesting and dangerous part of the work.

The caisson was a huge box-like structure with one open end resting

THE NEW CONNECTICUT BRIDGE, LOOKING EAST



U. S. SENATOR MORGAN G. BULKELEY, PRESIDENT CONNECTICUT RIVER BRIDGE COMMISSIONERS

upon the bottom of the river and having, a short distance up, a roof-like partition, which made a working chamber for the men, while the upper open end protruded above the surface of the water and was constantly added to, as the caisson was sunk into the bed of the river, to keep it above the surface of the water.

As a caisson was too heavy and bulky to be constructed upon the shore and then moved into place, it was built on a large pontoon made in halves and bolted together at the centre line. This pontoon was only 1 foot deep, the ends and sides being formed of 1 foot square beams and the bottom of 3-inch planking, all joints being caulked to make them water-tight. The sides of the caisson were then built up of one foot square beams piled in horizontal rows, and were held together and braced by similar upright beams of varying lengths, the whole being firmly bolted together. At about 6 feet from the bottom edge of the caisson a partition was inserted, which served the two-fold purpose of making an air-tight chamber underneath, where the men dug out the earth for sinking the caisson, and a floor which held thousands of tons of concrete, which were dumped in from above, thus forming the pier. This partition was, therefore, made very strong and, in seven of the caissons, was composed of three layers, and in the largest two of four layers of 1 foot square beams, making a total thickness of 3 and 4 feet, respectively, of selected long-leaf yellow pine.

To keep the working chamber free from water an air pressure was maintained, by means of a large air pump, at a pressure above atmosphere, varying from two pounds per square inch when the chamber was a short distance below the surface to thirty pounds maximum when at its lowest point, accompanied by a freshet. Fifty pounds is about the maximum that the workmen can stand.

To provide for the entrance and egress of men and material, three shafts were inserted through the roof of the air chamber, or caisson

JOHN T. HENDERSON, ENGINEER OF THE HARTFORD BRIDGE

proper, and extended up to the top of the open end of the caisson, which was really a coffer dam. These shafts were of sheet iron, of boiler construction, 30 inches in diameter, and two were used for removing the dirt and admitting the concrete, while the third, which was in the centre, was for men. As the air pressure had to be maintained in the caisson at all times, these shafts were provided with air-tight locks. Over the top of the main shaft was a door, and below this a distance of about 8 feet was another air-tight door, the two forming an air lock, which was raised as the caisson sank. On entering the lock, the man climbed down an iron ladder, closed the top door, passed through and closed the second lock, and was then in the middle section, which could be lengthened to keep pace with the sinking of the caisson. This section had, at the lower end and about 8 feet up from the working chamber of the caisson, a safety door, which opened downward and was held in place against a rubber gasket by the pressure of the air beneath it. The workman then opened a compressed air valve, which caused the air pressure to rise till it equaled that in the caisson, when the lower door would drop open. A method the reverse of this was used for leaving the caisson.

To allow the caisson to sink more easily into the earth, the 12-inch edge was beveled, and was protected by an 8-inch by 2-inch channel iron. The coffer dam, which formed the upper part of the caisson, was braced with sets of horizontal transverse struts 20 feet apart and two lines of longitudinal braces 10 feet apart. After the caisson was built up to a height of about 26 feet, the bolts joining the two halves of the pontoon were removed, water allowed to enter them, and, after sinking under the weight of the caisson, they were pulled out, when the caisson was ready to be towed into place.

In places where the river was less

PIERS READY TO RECEIVE THE ARCHES. TEMPORARY BRIDGE TO THE RIGHT

BREAKING THE ICE WITH A FLOATING PILE DRIVER. THIS DEVICE KEPT THE CHANNEL CLEAR FOR CONSTRUCTION CRAFT

than 10 feet deep it was necessary to use powerful steam shovels or dredges to cut a channel, the sand and gravel being dumped into scows and used for filling in the approaches. Groups of temporary guide, mooring and fender piles were driven on one side of each caisson to secure it in position, and on them were set stiff-legged derricks for handling the excavated material from inside the caisson and also the concrete and stone for the pier.

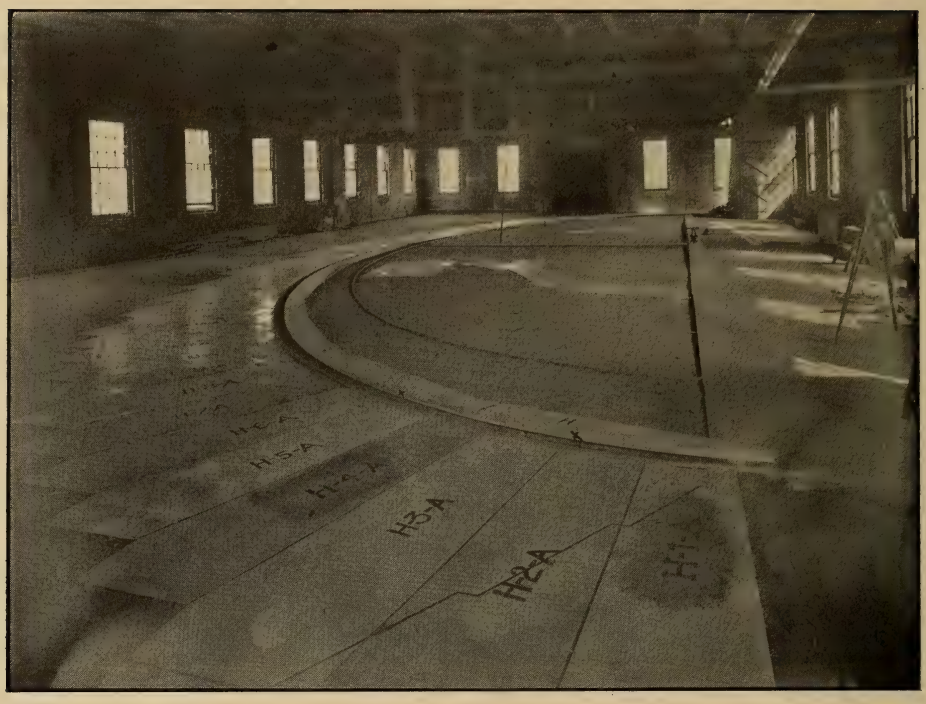
The concrete plant was a large, 40-foot by 220-foot railroad barge, and on a 40-foot high framework in the centre were two-bottom hopper bins, with a capacity of 25 cubic yards each. Each bin had two chambers, one containing sand and the other broken stone, with a space between for emptying bags of cement. On a track below ran a steel-bottom dump car, which was moved back and fourth under the different bins by means of a wire cable attached at either end of the car and operated by an engine. Graduations on the sides of the car indicated the correct amounts of stone, sand and cement for the different mixtures. The contents were delivered to a Carlin mixer, with a capacity of two cubic yards, mixed with water, admitted through hollow trunnions, and revolved from seventeen to twenty-five times. The mixture was then discharged into a steel bucket mounted on a small car. The bucket was then picked up by the derricks and its contents dumped into the coffer dam to sink the caisson and form the foundation. This method of handling the concrete is a very effective one, the best record being the placing of 320 cubic yards in a coffer dam in one ten-hour shift. The lower section of the first or shore caisson was 22 feet by 103 feet by 14 feet high and weighed about 3525 tons, and it was stated that 130 tons of concrete and stone were required to cause it to sink into the earth 1 foot.

The "sand hogs," as the men working in the air chamber are called, dig carefully about the edge, allowing the caisson, weighed down with stone and concrete dumped in on top of the partition, to sink and, as it is patent that the pier must be absolutely perpendicular, levels are taken every morning, and the foreman in charge of the "sand hogs" knows then exactly where to dig to correct the level.

The impression that these labourers get fabulous wages for their undesirable work is wrong. For a day of eight hours, including a half-hour at the surface for coffee and rest, they were paid $2.50 till a depth of 55 feet had been reached, and then, on account of high air pressure, their day would be decreased to six hours and their wages increased to $2.75. Another raise of 25 cents was given while the concrete filling was being done inside the caisson, as the slaking lime made the temperature high, accompanied by an irritating odour. Burly negroes were generally employed in this exhausting work. A twenty-four-hour day was divided into three shifts of eight hours each, and sixteen men constituted a shift, the maximum output for a day being 300 buckets of sand, at one-half cubic yard to the bucket. When bedrock was reached it was leveled off until the variation was no greater than 1 foot, and then the concrete was let down the material locks and the final operation had commenced. The concrete was tamped in leaving a constantly decreasing space till there was room for but one man, who could stand only by poking his head and shoulders up into the main shaft. When this last man ascended, the locks were removed from all of the shafts, the material shafts were filled with concrete, and a thin mixture of almost pure concrete and water was poured down the main shaft with an 8-foot head extending up the shaft, which forced the mixture to percolate into every crevice left by the workmen.

The concrete pier was then ready

INTERIOR OF CAISSON, ABOUT 40 FEET UNDER WATER. CHIEF ENGINEER GRAVES ON THE LEFT



LAYING OUT THE ELLIPTICAL ARCHES ON THE MOULD-LOFT FLOOR

to receive the crown of Leete's Island granite, and after the stone work was completed well above the waterline, the walls of the coffer dam were cut off by a submerged saw on a pile driver at about 5 feet below the low waterline. These submerged pine timbers will last indefinitely, and F. Hopkinson Smith has recently stated that he saw, in Venice, a pile removed from the water that had been in place at least 800 years and was still in a condition of perfect preservation.

One of the unique features of this bridge was the care taken and the method employed to make the intrados, or curve of the arch, a perfect semi-ellipse, it being customary to approximate this elliptical shape by the use of six or seven radii. A large loft without columns was selected, the floor leveled, and a rectangle, 22 feet by 110 feet, was covered with $\frac{3}{4}$ by 12-inch planed boards, screwed down. The two axes of an ellipse were then laid out by means of a transit, and upon the transverse axis points 1 foot apart were marked on square pieces of sheet zinc, the centers being marked by two intersecting scratches. From these points, using an ordinary pin as a rod, perpendicular lines were drawn, and upon them were marked off the ordinates of the ellipse, as found by solving its equation. The points thus found were joined by $\frac{7}{8}$-inch square pine splines, nailed tightly in place 1-32 of an inch from the required position, and sprung to conform to curve. The voussoirs, or stones forming the border of the arch, were then laid out with this semi-ellipse as a base and sheet-zinc templets cut out with a diamond-pointed tool. These templets were sent to the stone yard, enabling the stones to be made accurately to size. The photographs showing the accurate and graceful curve of the arches are evidence that this method has proven entirely successful. The voussoirs were made of best selected

A VIEW OF ARCHES AND CENTERINGS DURING CONSTRUCTION

CONSTRUCTION OF THE ARCHES, SHOWING THE PROJECTING STONES AFTERWARDS COVERED WITH CONCRETE

CONSTRUCTION OF ARCH SPANDRELS

granite, with the grain or lift of the stone in a radial direction, or transverse with the length of the bridge.

When the blocks for the arch were to be put in place a wooden false work was erected, which rested on piles and supported and formed the arch during construction. The stones, each of which was designed and numbered for one particular position, were put into place successively with a $\frac{3}{8}$-inch space left between, and the outer edge was caulked, to give the correct separation and to hold the special Alpha brand cement, which was poured in between. The cement was tamped in uniformly by means of a $\frac{1}{8}$ by 4-inch steel plate, after which the caulking was removed and the depression filled in with cement—an operation termed "painting." The soffit, or interior surface of the arch, was made of stones of varying vertical dimensions, so that, looking down upon it at this stage of construction, it presented a checkered appearance, with part of the stones projecting from 2 to 4 feet above the others.

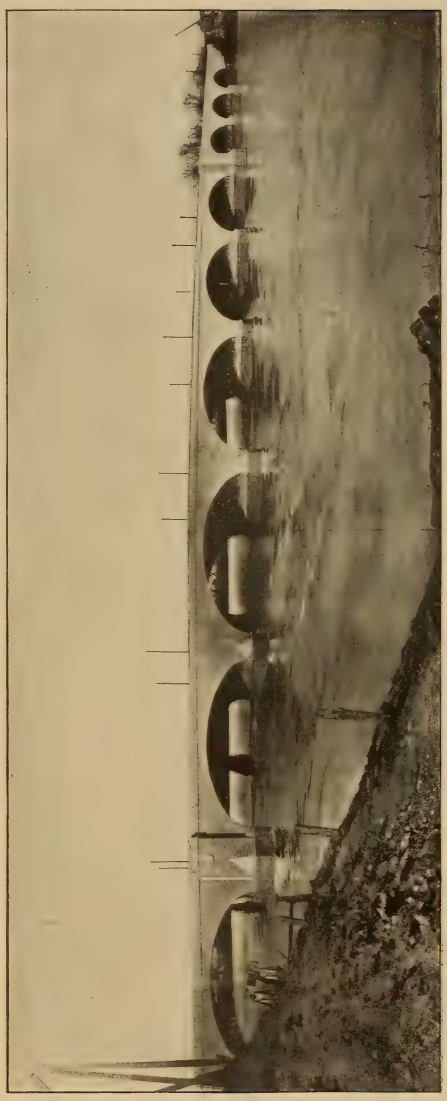
Into this corrugated surface concrete was poured which, on hardening, bound the whole together into one homogeneous mass which formed the main compression member of the span. After allowing the concrete to "set" for from four to six weeks, the false work was removed by gently knocking out the greased wedges which held it in place.

The parapet, or railing around the top; the spandrel, or the vertical side walls between the parapet and the voussoirs, and the soffit, or lower surface of the arches, are all faced with the hard, tough and beautifully marked Stony Creek granite, and the two latter are backed with concrete. The tops of the arches, after being filled with concrete, and the backs of the spandrels were finished with cement mortar, troweled smooth and water-proofed with three layers of tar paper coated with hot coal tar pitch. A 6-inch layer of clean sand

protects this coating and covers tile drain pipes, which carry away water that might collect through the arch, into the river. Above this is a fill of clean sand in layers up to the under side of the pavement. The roadway is paved with an 8-inch concrete foundation and a 1-inch binder course, of cement and fine trap rock, covered with a 2-inch layer of Trinidad Lake sheet asphalt, and the sidewalks are of cement, laid in blocks in the usual manner. All telephone and telegraph wires are carried in glazed, water-proof clay conduits running under the sidewalks, and may be reached for inspection or repair by means of numerous man-holes. Down the centre run two street railway tracks, with the 9-inch grooved girder rails laid on 6 by 8-inch yellow pine ties. The roadway at the centre is approximately 50 feet above high water, and, in either direction from the centre, is graded downward in a parabolic curve for a length of 339.5 feet on one side and 388.1 feet on the other, while from the ends of these curves it is sloped in straight lines to the abutments, with a pitch of 2 per cent. and $1\frac{3}{4}$ per cent., respectively. Ornamental electric lamp-posts, also serving as trolley-wire poles, are located in the centre of each span and over each pier. Observation alcoves are formed by the sidewise extension of the sidewalks over the wide abutment piers.

The filling required 283,000 cubic yards of material; 133,000 cubic yards for the approaches to the bridge, most of which was used at the west end, and 150,000 cubic yards for the railroad construction work, and it was decided by the contractors that the cheapest method of getting this large amount of filling was to take it from the river bottom by means of the centrifugal pump system.

The plant consisted of a 20 by 60-foot flat-bottomed scow, containing a 200 horse-power engine with two boilers and a 14-inch discharge centrifugal pump with vanes 45



THE COMPLETED BRIDGE ACROSS THE CONNECTICUT RIVER AT HARTFORD

inches in diameter, which drew up the sand and water through a 12-inch spiral-riveted steel pipe, 20 inches long, covered with asphalt and tar to protect it from corrosion. At the bottom of this pipe was fixed a steel funnel with a 1 by 3-foot mouth, which was protected by a stout 4-inch mesh wire screen. Across the mouth of the funnel was an agitator, which consisted of a horizontal pipe with four pipes protruding at right angles. A high-duty pump on the scow threw a powerful stream of water

HARTFORD BRIDGE, LOOKING EAST

through a 3-inch pipe leading to the agitator, where the water stirred up the sand, and this mixture, containing from 10 to 25 per cent. of sand, was sucked up by the pump. The pump had a capacity of about 4,200 gallons the minute.

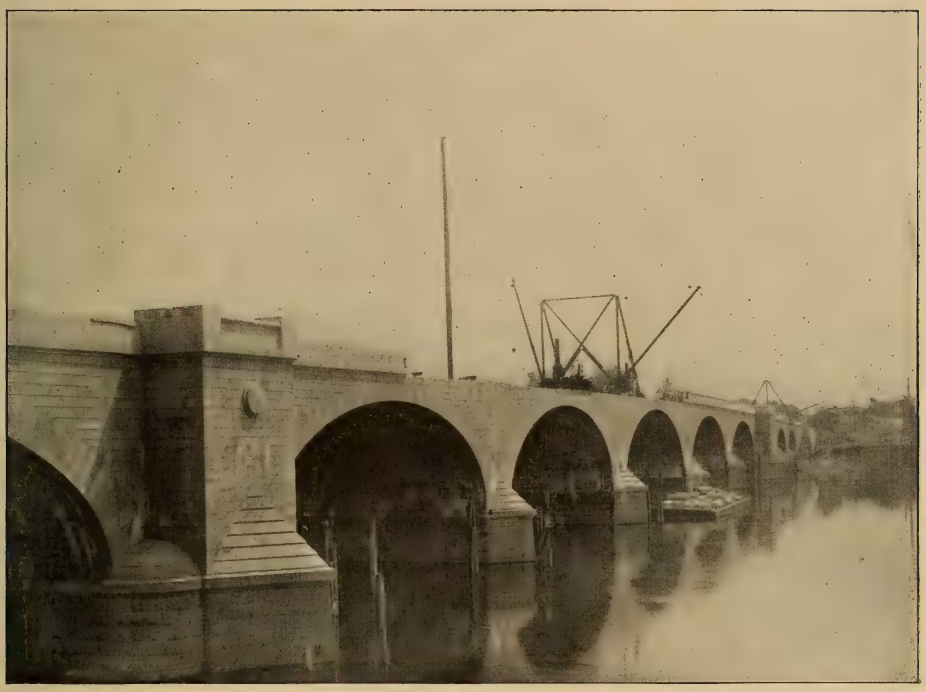
The mixture of sand and water was carried through a pipe line 1,500 feet long, made up of 14-inch spiral, riveted steel pipe in 20-foot sections, joined together by rubber joints, and was carried across the channel of the river on temporary piles, high enough to allow small river craft to pass under, while for the remainder of the distance it rested upon pontoons anchored in the river. The shore end of the line emptied into a long, wooden framework of irregular section, which was on the site, and was built in the form of the railroad embankment, and which allowed the water to drain through, but retained the sand.

One of the circumstances attending this process afforded considerable amusement to all except "Pomp" Turley and, perhaps, the Bridge Commissioners. Most of the sand came from a little island located just north of the old temporary bridge, and known by the euphonious title of Dog Island. This island came into existence during the present generation, and was formed by the sand which gradually collected about the hulk of a wrecked sail boat until it assumed the dignified proportions of an island about 300 feet long—in low water. It was in a little clump of seven or eight willows bravely perched on the highest point of the island that "Pomp" Turley and his son "squatted" and built them a board and canvas shelter. During high water these followers of the simple life were forced to retreat into a sort of tree-house built some 10 feet above the island. It is little to be wondered at that when the contractors wanted to suck up the real estate from under "Pomp's" very roof-tree he objected and refused to vacate, except to his own financial advantage. But at about this time he fell into the clutches of the law, owing to the fact that the judge refused to believe that numerous Sunday fish-and-beer parties were conducted on a philanthropic basis, and as all he got from his friends was sympathy, it is feared that a land-mark, so long an object of curiosity, if not of pride, will be ground away under the iron wheels of progress.

The three men who were directly responsible for the construction of this civic monument were Senator Morgan G. Bulkeley, of Connecticut, president of the Bridge Commission, and Edwin D. Graves, M. Am. Soc. C. E., who was chief engineer until sickness forced him to surrender his post to John T. Henderson, who completed the work.

United States Senator Bulkeley was chosen president of the Bridge Commission because of his masterly grasp on local conditions, his supe-

DOG ISLAND DURING A FRESHET



LAYING THE RAILING OF THE COMPLETED BRIDGE

rior qualifications and success in business, and on account of his prominence and prestige in government affairs. Born in East Haddam, in 1837, Senator Bulkeley is now in his seventy-first year; but, in spite of a lifetime of greatest activity, divided between serving his country in peace and in war and caring for his large business interests, he is still a remarkably active man, displaying force, character and vigour in every movement.

He went into business in New York in 1851, and when the Civil War broke out went to the front with the Thirteenth New York. In 1872 he went to Hartford to attend to the various business interests left by the death of his father. He was elected a director of the Ætna Life Insurance Company, the president of the United States Bank and, later, president of the Ætna Life, a position he still holds. After serving as Mayor of Hartford from 1880 to 1888, he was elected Governor of the State for two successive terms, and in 1905 he was sent to the United States Senate. Senator Bulkeley has always been a prominent figure in the social life of the State and a leader in a half-dozen patriotic and military societies.

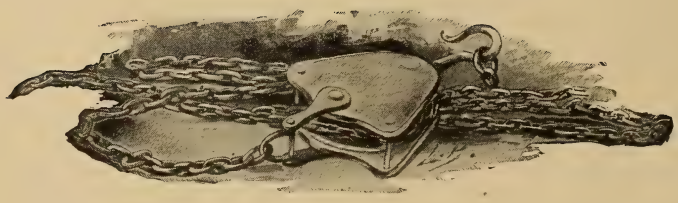
Edwin D. Graves, chief engineer, was, to a large extent, responsible for the symmetry of outline and strength of design, as it was he who prepared the first plans submitted to the commission and afterwards the plan for the bridge as it has been built. Unfortunately, the strain of too close application to work broke down his health and, about a year ago, he was forced to relinquish his position. He was born in 1865, at Orono, Me., and was graduated from the school of civil engineering at the University of Maine. He then began work in railroad construction in his native State, and became chief engineer of the Somerset Railroad, which office he held till 1890, when he moved to Connecticut. Here he de-

voted himself to bridge building and designed several of the bridges across the Connecticut, and in 1896 was appointed chief engineer of the Connecticut River Bridge and Highway Commission. Mr. Graves is a member of many social and engineering societies, including the American Society of Civil Engineers and the Engineers' Club, of New York.

John T. Henderson, deputy chief engineer, was appointed to fill Mr. Graves' position about two years ago, and as he had been connected with the commission for nine years and had been an active and influential participant in all of its engineering work, the construction was pushed forward with precision and energy.

Mr. Henderson was born on a farm in Cecil County, Maryland, in 1876, and obtained his civil engineering education at Delaware College, Newark, Del. He then spent about two years in surveying and bridge engineering, after which he was connected with the consulting engineer's office of the Manhattan Elevated Railway Company, leaving this position for that of draughtsman for the late Wm. Rich Hutton. Later he became connected with the Connecticut Bridge Commission, and finally was promoted to the position he now holds.

Mr. Henderson is a member of the American Society of Civil Engineers. As assistant to Mr. Graves, he designed and inspected eight steel railroad bridges on the line of the Greenwich & Johnsonville Railroad near Albany, N. Y., one of these being built across the Hudson, a steel highway bridge across the Penobscot, and a 400-foot suspension bridge across the Kennebec River at Waterville, Me. His later work has been devoted to the plans and estimates for the numerous designs for the bridge at Hartford and the construction of which for the last two years has been under his supervision.



BRITISH RAILWAY DEVELOPMENT, PAST AND FUTURE

By F. A. Lart, A. M. I. C. E.

PART II.

IT will very probably be found, if indeed it has not been already sufficiently proved to the satisfaction of the public and of many professional engineers, that the much-talked-of and zealously advocated electrification of existing or any future main line railways, so far from affording an economical and otherwise satisfactory solution of the problem of British railway development, will have exactly the reverse result if any railway company has the fatuity to attempt such a change, whether wholly or partially.

The partial electrification, as regards certain local services, carried out or projected on the North-Eastern, Lancashire & Yorkshire, London, Brighton & South Coast and London & North-Western Railway systems is, in each and every case, a false move in the writer's opinion, and that of perhaps the majority of professional engineers also. Whether the performances of such electrified sections of these important railways will rightly square with the accounts presented on their behalf, is a question of interest and importance to shareholders, at any rate. How do the existing and altered conditions of things compare? We have, on the one hand, a simple permanent way of the usual type, and running on it self-contained steam locomotive power and simple rolling stock, all representing considerable capital outlay, maintenance charges and earning capacity.

With such a system, the failure of any individual self-contained locomotive, carriage or wagon unit causes merely local disablement, and leaves undisturbed and unimpaired all the remaining units in service at the time throughout the entire railway system. Of course, the failure of any particular train causes more or less delay and inconvenience to trains following it in that particular district, and perhaps also to those connecting with it, and incidentally to perhaps even wider spheres of action. But, generally speaking, delay or accident on any of the existing widespread trunk railway systems of this country, especially those possessing duplicate roads, has a restricted and merely local effect, and none at all on the intricate working of that system as a whole.

Contrast all this with the new order of partially or wholly electrified railway systems as converted from their original simple conditions.

The permanent way holds good so far only as it carries the rolling stock passing over it. There has to be added to it the highly expensive and death-bearing equipment of one at least, and usually two, "live" rails carrying the electric current. These rails cost in themselves just as much per mile as those carrying the rolling stock, and their general "bonding" connections, insulating gear, crossings and connections with the

various sources of electric current, and the general upkeep of the whole are at least as costly per mile as the rails, sleepers, chairs, keys, fish-plates and points and crossings of the simple, ordinary permanent way. The capital and maintenance costs of the original permanent way are thus at once practically doubled.

There is then to be provided the electrical power for driving the trains running over that particular "electrified" section of the line (which may be, and usually is, also used by the other locomotive-drawn trains) in the form of a high-pressure and high-power current, conveying instant death to any living thing which may happen to come in effective contact with it, and setting up a peculiar decay in metallic objects nearly adjacent to its return path through the earth and parallel to the line, such as gas and water pipes, and occasionally inducing explosion of gas in the said pipes and bursting the cables and feeders along which it is delivered from the power houses. The cables conveying the electric current constitute a further addition and complication of an extremely costly nature, and themselves require the most complete insulation throughout, together with numerous connections with the conductor rails through which the electrical current or power eventually passes to the driving machinery on the coaches or the special locomotives employed to haul them.

In the mere conveyance, therefore, of the electrical power from the generating stations to the conductor rails a highly complicated and costly plant, involving expensive supervision and upkeep, has to be provided throughout the entire length of the railway concerned. But this is not the last or most expensive detail of electrical railway equipment required.

There has to be further provided an adequate source or development of electrical energy in the shape of large and costly prime power developing machinery, such as steam engines with boilers and accompanying subsidiary plant, or gas engines with their particular auxiliary machinery, and their respective sources of energy in the shape of coal or other fuel and water or some kind of explosive gas which itself requires to be produced in some way from some elementary source or other.

Further, such plant has to be provided in duplicate, triplicate or any higher degree corresponding to the smallest possible number of sections into which the line has to be divided up, throughout its entire length and with special provision for a terminus at each end and for any complex intermediate junction or goods yard, since it is absolutely impracticable to supply one single and unbroken power current throughout the entire system.

Again, each such divisional power supply plant naturally requires an expensive power station to house it, and on such power stations, with their necessary outside accommodation in the shape of yards for storage of coal and various materials, and sometimes residences for the men in charge, the familiar toll of local and general rates and taxes is levied. Also, on all such power plants, power houses, accumulated materials, and so on, heavy insurance premiums have to be paid.

But even this is not all, for in every stage of the developments of (a) primary power as represented by steam or gas engines, of (b) secondary power as represented by the electric force generated in the electrical machinery producing it, of (c) the conveyance of the power current to and throughout the conductor rails and thence to the trains themselves by some system of contact moving with every train and possibly current vehicle of such train, and (d) of the conversion of the power current into mechanical motive and tractive power in each train—in each and all of these, and indefinitely multiplied more or less in accordance with the number of trains or individual vehicles moving on the rails, there is serious and inevitable wastage

and dead loss of power, no matter how "efficient" the system and the plant employed may theoretically be. This should be self-evident, and the question of efficiency we may examine in some detail presently.

With these detail particulars of electrical railway working before us, we can make some easy comparisons, without being too technical or too minute as regards figures, with the existing simple methods and details of railway working.

Firstly, then, the capital and maintenance costs of the permanent way are increased outright by, let us say, 75 per cent.

We must then add the capital and maintenance costs of the cables and connections conveying the electrical power current from the generating stations to the rails, and this may be fairly estimated as equal to a further 25 per cent. on the original and maintenance costs of the line, so that even so far such costs are increased by 100 per cent., i. e., doubled.

The prime capital costs of the electrical power generating plant and the requisite power houses depend on a variety of considerations—strength and quantity of current required for working any estimated maximum amount of traffic, the requisite number of such power units, and so on; for a length of line of, say, 50 miles, we may roughly estimate such costs at £250,000.

On such plant and accompanying equipment will lie a perpetual annual charge in respect of depreciation, rates, taxes, insurance, wages and, if we like to include them, fixed charges, such as interest on capital cost and interest on the whole capital of the company.

We may remark here that the generating and entire electrical plant involved on such a line is necessarily in constant use throughout the whole year and the whole life of the line, although the output of power necessarily varies according to the fluctuating traffic requirements; and, further, the fluctuating demand for and output of power is quite the most mischievous and expensive feature of the working of any electrical system. Under these circumstances it is obvious that any main unit of electrical power developing plant must be constituted (a) in excess of actual maximum requirements, and (b) in a sufficient number of units to provide adequate reserves in case of failure of any units actually in working and capable of developing the said maximum power required—in fact, both the excess gross power and the excess detail power units require, in each station, and, therefore, throughout the entire system, to be practically doubled. To work on any smaller margin is to incur almost inevitable disaster, sooner or later, and, of course, when least expected or desired.

This brings us to a very important and vital feature in electrical railway working in itself and as compared with the ordinary system in use—the failure (a) of individual train units and (b) of any self-contained section of electrically worked line. When an ordinary steam locomotive fails, it is a comparatively simple business to provide another; so also with any carriages or wagon or entire train, delay and inconvenience of greater or less degree being inevitable in any case, of course. But with electrical locomotives, or self-propelling coaches or wagons or whole trains, such failures almost necessarily and inevitably not only cripple all the remaining vehicles of such a train, but have a dangerous tendency to paralyze the entire electrical equipment of the section on which such accident happens to occur.

In such case, not only is the entire traffic which happens to be passing on that particular section hopelessly paralyzed, but also the entire working of the rest of the line, on either side of the damaged section, is, sooner or later, held up, and all "through" traffic completely and effectively prevented. In fact, such widespread and wholesale interference

with the working of the line—always a delicate and easily deranged organism—is, fortunately, quite impossible under the normal railway system, and only characteristic of and to be looked for on electrical railway systems. If it be urged by interested persons that electrification of existing lines or the construction *ab initio* of electrical railways has been, is, and always will be carried out in such a way and so thoroughly and efficiently as to, humanly speaking, preclude the slightest chance of failure, railway shareholders and unconvinced professional engineers can only point to the everyday examples and experiences that lie before us in this country alone, and pertinently argue that such immunity from failure is not only absolutely unattainable, but has to be assured (*sic*) by extraordinary precautions and at an overwhelming cost. It is hardly necessary to labour this irrefutable point of doubly expensive electrical as compared with ordinary railway working. But it is as well, perhaps, that those who are not professionally, technically, financially or otherwise competent to properly estimate the pros and cons of this important question should have placed before them sufficient and sufficiently reliable information to at least enable them to form some judgment of their own, and especially those who are financially interested in the railways of this country as shareholders.

As to the question of "efficiency," then, in the working of either railway system. Of this question there are two main aspects—the personnel and the power.

As regards the permanent working staff, there can be, and there is, no difference whatever between the requirements of either system, from the general manager to the porter, through every grade. On electrical railways, however, we have seen that the complication of the permanent way, the sub-division of the line into electrical power sections, and the corresponding provisions of power current and power stations require so much extra human labour.

As regards the working of signals and points and crossings, the Board of Trade require rather more intricate methods of "absolute block" working than even they do on ordinary railways; that means at least as many "sections" of the line and a corresponding number of men.

The number of trains running on electrical railways is almost invariably greater per day than on ordinary lines; this, in fact, is one of the foremost and most potent claims raised by electrical railway enthusiasts in commendation of, and insisted upon as an apology for, the conversion, construction or existence of such railways. Each train necessarily requires a driver and assistant (as in the case of all steam locomotives) and at least two attendants or "guards"; in some cases, as on the London electrical railways, one such attendant is required for every two passenger coaches. In these respects, therefore, the personnel of every train is not less than what is required on ordinary railways; it may be more, up to one or two hundred per cent.; and more trains are run per day and per annum, partly, no doubt, with the same staff, but not so as to require less, probably, than an increase of 20 per cent. in such staff.

It is usually claimed that the increase of train attendants causes a reduction in the platform staff of each station. But to what extent can the number of porters be reduced? Certainly not in the same proportion as the average train staff is increased, because the duties of a porter are not by any means confined to waiting on trains or even to handling the luggage of and otherwise assisting passengers. The other duties required of them are at least no less on electrically worked railways than on the ordinary ones.

We have now to consider the question of motive power. On ordinary railways the great majority of trains

are drawn by a single steam locomotive of varying type, size, weight and power, of course, but in every case completely self-contained and constituting a combined prime power generator, prime mover and prime tractor; the locomotive may either itself carry the prime power-producing elements, coal and water, or in a tender attached to, and practically forming part of, itself. Such locomotives are, as machines and as performing all their several necessary functions, of fairly elementary simplicity, though modern developments have, unfortunately, tended to that mechanical intricacy and that uncalled-for, undesirable and uneconomical increased size and weight which have already been deplored in these lines.

The prime costs, maintenance charges and working economies of these steam locomotives necessarily vary in individual cases. That they are highly efficient as regards their fuel and water consumptions per unit of gross net (tractive) power development cannot, unfortunately, be claimed for them, for the simple fact that from 25 to 30 per cent. of the coal fuel burnt in the fire-box of any one of them is, in one way and another, absolutely wasted and lost. This is due to various causes, among them inefficient means and methods of combustion, and inefficient, careless and deliberately wasteful drivers and firemen acting in obedience to the prevailing "principles" of the trades-unionism which enslaves and demoralizes every type and every grade of the so-called "working classes" at the present day. The actual working efficiency, therefore, of an average steam locomotive cannot be estimated as higher than 70 per cent. of what should theoretically be developed from the coal and water actually consumed and converted into steam and from the steam so generated.

When two locomotives are required, as sometimes happens, to draw a single train, or where a locomotive of excessive size, weight and power is put to draw a small train far below its full or normal capacity, this waste of power and low efficiency represent a still more reduced economy of working.

Now with regard to electrical motive power. This takes the form either of a separate locomotive attachable to and pulling a train of "free" carriages or wagons, or of motors attached to some or all of the axles of such individual vehicles or complete trains. We have already considered the loss of purely mechanical power, as originally developed from the coal consumed, and the water converted into steam, or as developed from coal or other combustible elements alone converted into gas, and through each succeeding stage of conversion into mechanical propulsive and tractive effort acting on the driving wheels and the rails.

We can similarly trace the evolution and reduction of electro-mechanical efficiency through the several stages of its development from the coal burnt to the actual movement of the train on the rails, and thus compare the unavoidably greater losses incurred in electrical power traction as compared with steam power locomotive traction in railway working.

Assuming that a train of 250 tons total weight, inclusive of engine and tender, or of an electrical locomotive requires the expenditure of 50,000 "horse-power" (the conventional expression for the unit of power) to run 50 miles in one hour, the steam locomotive possessing an efficiency of, say, 70 per cent., will require to develop

$$50{,}000 + \frac{50{,}000 \times 30}{100} = 65{,}000$$

horse-power in order to perform this task.

The electrical horse-power which will have to be developed at the outset (i. e., in the steam or gas engine which drives the electricity generators which, in turn, supply the electric power current to the conductor rails and thence to the mo-

tors on the locomotive or on the coaches themselves, which, in their turn, convert this electrical energy into rotary action and tractive effort in the wheels and on the rails) will have to be sufficient to cover all the inevitable losses or reductions of efficiency which occur at each of the above successive stages; and we arrive at the required figures in this way, making reasonable assumptions as to the various efficiencies based on practical knowledge and experience:

(1) Efficiency of motors on the wheels of locomotives or of coaches, and assuming it a constant in either case = 95 per cent. Therefore, horse-power required to be put into these

$$\text{motors} = 50{,}000 + \frac{50{,}000 \times 5}{100} =$$

52,500.

(2) Efficiency of conductor rails and of contacts of the rails with the motors through the sliding shoes or other means employed, i. e., losses due to leakages, sparking, etc., in either case = 95 per cent. Then horse-power required to be put into the

$$\text{rails} = 52{,}500 + \frac{52{,}500 \times 5}{100} =$$

55,125.

(3) Efficiency of conductor cables (from generators or transformers) and connections with conductor rails = 97 per cent. Then horse-power required to be put into these con-

$$\text{ductor cables} = 55{,}125 + \frac{55{,}125 \times 3}{100}$$

= 56,778.

(4) Efficiency of electrical generators (or of generators and transformers combined if an alternating current is primarily developed and thence converted by means of transformers, which are separate and additional machines, and, therefore, constitute a further addition to and complication, and prime and maintenance expense in the generating plant) = 93 per cent. Then horse-power required to be developed in the

$$\text{generators} = 56{,}778 + \frac{56{,}778 \times 7}{100}$$

= 60,752.

(5) Efficiency of steam or gas engine plant, including the boilers or gas generators driving electrical generators; this we are bound to take on somewhat the same basis as we estimated the efficiency (net) of the steam locomotives upon, and it cannot be taken at any higher figure than 85 per cent. This engine, or these engines, therefore, require to develop the following horse-power:

$$60{,}752 + \frac{69{,}752 \times 15}{100} = 69{,}864.$$

This is 4,864 horse-power in excess of that required to be developed by the steam locomotive to perform similar work, or an increase of nearly $7\frac{1}{2}$ per cent.

With regard to the assumed 85 per cent. efficiency of the engine plant driving the electric generating plant, as compared with the assumed 70 per cent. efficiency of the steam locomotive, in the former case the conditions are such that, though there are two or three quite separate stages involved, as compared with the entirely self-contained locomotive power generator and tractor, yet such items of plant are usually worked more economically in each case and in combination than the single locomotive. Also, the locomotive item required for the single train represents only a proportion of the electrical power plant and of its power output, and, therefore, the reduced efficiencies of the various stages enumerated above must be modified accordingly.

This has, in fact, been done, and though the allowances and results expressed in the above figures are only to be taken as approximate, they certainly do not err on the side of excess as against this electrical railway power. By generalizing in the above manner, the economy of the system

shows more favourably than would result from a more detailed and minute examination of any individual case of train working. In concluding, we may emphasize this fact by considering the details of electrical motive and tractive power. The amount of power required for running any particular train under any particular circumstances of distance, weight, time and speed, and any intermediate stoppages involved, can be estimated with a fairly close approximation; the most economical development and expenditure of this electro-mechanical motive force in the train concerned is a more uncertain matter. It is considered by some engineers that a single locomotive attachable to each train, and of a sufficiently wide range of power to deal with great as well as moderate and small loads, is more economical than placing upon each coach or wagon of any train a motor capable of running that coach or wagon fully loaded at the maximum possible speed required; or such vehicle may carry with it one, or perhaps two, "idle" vehicles not themselves possessed of any motive power. Either condition involves, as in an ordinary steam locomotive, the disadvantage that a full-power motor is necessarily most uneconomical when not working up to its full capacity; that should be obvious, but in any case this condition is quite unavoidable in any type of locomotive. In the case of a separate locomotive for each train, the various losses and the reduced net efficiency are probably less than the accumulated losses and total reduced net efficiency obtained from a number of comparatively small-power motors on individual vehicles. On the other hand, the capital and maintenance costs of any given number of such small vehicle motors representing the same total power as a locomotive capable of dealing with that number of "idle" vehicles, will probably exceed the capital and maintenance costs of such a single locomotive.

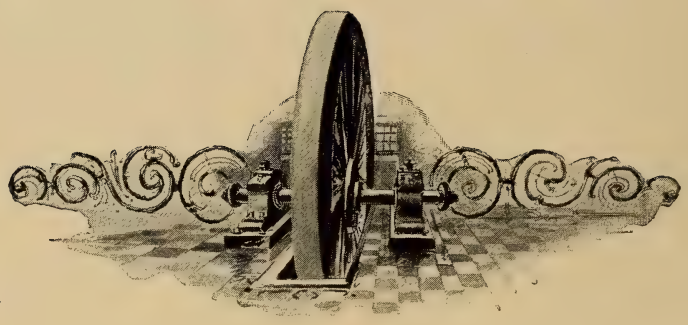
The failure, however, of any single locomotive cripples the whole train which it is required to deal with and necessitates the provision of another similar locomotive. The failure of any individual motor-vehicle, on the other hand, does not (necessarily) affect the remaining vehicles of the train, and the combined power, or margin of power, of these would, no doubt, be sufficient to run the entire train, including the powerless coach, as if such coach had not failed at all or were merely an "idle" vehicle.

The writer is, indeed, not prepared to say which system is the most economical, nor does he think that sufficient experience has as yet been obtained for determining the point. Much depends on the general or particular character of the traffic carried on. Much has yet to be learnt also as regards every detail and every aspect of electrical railway working. But the writer personally believes that enough has been experienced and proved to show pretty clearly that there are certain very definite limits to electro-motive power and to the supposed economies resulting therefrom, such as certainly do not justify the full claims made by electrical enthusiasts for this type of railway working. These ascertained facts should give pause to directors and shareholders of British railways in consenting to this radical change in the existing well-tried and more simple system of railway working, which has proved its utility, as well as its defects.

The increased utilization of existing, unaltered railways and their facilities by means of small and frequent train units, such as the new steam motor-coaches, would certainly be much more economical than any radical alteration to electrical working of local or main-line services. The coexistence of a dual system is essentially uneconomical.

Enough has been said to show that the development of British railways in recent years has been a very ex-

pensive matter, and it is common knowledge that this itself and the heavy capital and revenue expenditure required to meet it, together with the insolent and excessive demands of trades-union railway employees, fostered and exploited by paid professional agitators and subsidized idlers of the lower classes in Parliament and elsewhere, have all combined to reduce to a very serious degree the capital values, the earning powers and the divisible profits of the gigantic railway industries of Great Britain, on the efficient and economical working of which depend interests closely affecting all classes of society and commerce.



AMERICAN DOCKING FACILITIES ON THE PACIFIC COAST

By H. A. Crafts

ABOUT May 1 next, as all the world knows, the great fighting strength of the United States Navy will be assembled at San Francisco. This fleet will be composed of sixteen battle ships, six torpedo boats and four auxiliaries.

It is to be presumed that all these vessels were put in first-class repair before leaving the Atlantic coast; but it must be remembered that the hull of a sea-going craft is constantly exposed to the wear and tear of voyaging, as well as to the effects of the marine elements. A frame may be sprung by encountering some tremendous sea; a hull may be abraded or stove in by collision, and, at best, the paint of a bottom becomes scarred, rust attacks the steel hull, and barnacles will gather in spite of all precautionary measures.

So it has become a well-established nautical axiom that, even barring material damage to a hull, a ship, in order to be kept in first-class repair, must be put in dry dock at least once a year, that its bottom may be cleaned, recaulked and repainted.

Of course, no exception to this rule is made even in the case of a first-class battleship; on the contrary, the greater the value of a ship the greater the necessity of keeping it in good repair, below as well as above.

Such being the case, it is quite pertinent to know something of the facilities that will be found on the Pacific Coast for the repairing and renovating of the hulls of the great fleet that is now on its way to those waters.

It is well understood that all such work is performed by the use of dry docks. These docks are first filled with water, the ship needing repair floated in, the dock gate closed and the water then pumped out of the dock until the vessel stands high and dry upon the stocks. Then all parts of the hull are accessible to the force of repairers, and the work of renovation may proceed without hindrance.

Now there are two kinds of dry docks, the floating dry dock—such as the *Dewey,* that was manufactured on the Atlantic seaboard and towed all the way over to the Philippines for use in the port of Manila—and the graving, or permanent, dry dock, which is built into the land upon the sea or arm of the sea.

The floating dry dock is built of timber or steel, while the graving dry dock may be constructed of wood, stone or reinforced concrete.

When Admiral Evans' fleet reaches San Francisco it will be joined by two battleships, eight armoured cruisers and certain torpedo destroyers, so that the entire naval ensemble in San Franicsco Bay will number, in the aggregate, more than thirty-six war vessels of one kind and another.

In all probability this immense

force will be kept in Pacific waters for at least three years, with the naval base at San Francisco. Consequently, the dry dock facilities, even barring accidents to war vessels, will be taxed to their utmost in keeping the vessels making up the fleet in first-class condition.

It needs but a glance at the government dry dock facilities on the Pacific Coast to convince one of their utter inadequacy for the coming emergency, and to make it plain that private dockage will needs be engaged in order to keep up the necessary repairs on the naval vessels.

The United States Government possesses upon the entire Pacific Coast but two completed dry docks. These are graving dry docks; one is situated at the Mare Island Navy Yard, in San Francisco Bay, and the other at Bremerton, Wash., on Puget Sound.

The dock at Mare Island is 513 feet long over all, 80 feet and 7 inches wide at its entrance, and 27 feet and 6 inches deep over the sill. It will be seen that this dock will be available only for the accommodation of the smaller-sized ships.

The dry dock at Bremerton, however, is more commodious, being 650 feet long over all, 92 feet 8 inches wide at the entrance, and 30 feet deep over sill. The dimensions of this dock are such as to permit the entrance of the larger battleships, but, being situated so far distant from the main naval basis, will not so well accommodate the fleet as though it were located in San Francisco Bay.

At Mare Island, however, the government has under construction a third Pacific Coast dry dock; but it is estimated that it will take at least three years of hard work to finish it.

This dock was begun in 1900, and the contract called for its completion November 20, 1907; but unforeseen emergencies arose in the course of the work that delayed matters seriously, and the dock will hardly be available for use during the coming visit of the fleet to the Pacific Ocean.

The principal obstacle encountered in the construction of this dry dock was a lack of firmness of foundation. The ideal formation in which to build a graving dry dock is one of rock, easy of excavation; the next best is one of hard-pan; but when the constructors of the new dock at Mare Island began to dig for their basin they found a body of marsh land, so soft and so deep that the base for the dock floor had to be constructed on wooden piles, reaching down into the mud bottom from 50 to 60 feet.

Upon the top of this nest of piles the floor and superstructure, which are to be of reinforced concrete, will have to be built, a condition that renders thorough and substantial construction very difficult.

Work on this dock, in view of the arrival of the fleet on the Pacific Coast in the near future, will be pushed with all speed. The new dock, when finished, will be 720 feet long, 102 feet wide and 30 feet deep.

Outside of the government docks on the Pacific there is just one private plant on that coast which has facilities for handling the big battleship. This is situated at Hunter's Point, on the west side of San Francisco Bay, about five miles south of the city, and is owned by the San Francisco Dry Dock Company.

This plant, however, embraces only one dry dock capable of admitting the large battleships, this being 750 feet long, 122 feet wide and 30 feet 5 inches deep.

There are thus only two docks on the entire Pacific Coast of the United States capable of handling the larger of the navy's battleships, and one of these is a private one and will need to be leased by the year by the government in order that it may be at the navy's disposal at any and all times; otherwise, the government would have to take its chances with the merchant marine.

It would, therefore, look as if it would be a problem to afford the

coming Pacific fleet adequate dry dock facilities within the time when they are most needed.

Some time before the announcement of the proposed mobilization of the fleet on the Pacific was made the San Francisco Dry Dock Company had perfected plans for the construction of a dry dock which, when complete, will be unique in this class of marine engineering, in that it will be the largest dry dock in the world.

At the present time the largest dry dock in the world is at Belfast, Ireland; but the proposed San Francisco dry dock will materially exceed it in dimensions. In exact figures, the new dock will be 1,050 feet long, 144 feet wide and 34 feet and 6 inches deep.

It will be situated in close juxtaposition to the company's other docks at Hunter's Point. The ground composing the proposed site is underlaid at a depth of a few feet with what is known as green serpentine rock, which will not only be easy of excavation, but will afford a substantial foundation for the superstructure of the dock.

The interior facing of the big dock will be of reinforced concrete, averaging 15 inches in thickness.

The pumping plant that will be supplied with which to empty the dry dock will consist of four 54-inch centrifugal, double suction pumps, with a joint capacity of 200,000 gallons of water per minute.

Each pump will be driven by a 500 horse-power, three-phase electric motor, operating at 440 volts. These pumps will be located in the bottom of the pump pit, and can be started from the gallery at floor level, the intention being to use the high-tension current of some neighbouring power company, say at 10,000 volts, and transform the same to the requisite voltage.

With this installation it will be possible to pump 24,000,000 gallons of water in two hours, which will be sufficient to empty the dock.

This great dock will be constructed in contemplation of the continued increase in size of ocean-going steamers, and when complete will be of a size sufficient to admit a vessel 1,000 feet long, vessels of this length being already talked of as among the possibilities of the near future. To show the gradual lengthening of sea-going craft in the past fifty years the following statistics are given:

Year.	Length of Vessel.
1840	200 feet.
1855	375 feet.
1881	525 feet.
1905	675 feet.
1907	775 feet.

The construction and operation of the modern graving dry dock form quite an interesting study of engineering and mechanics. In the selection of a site for one of these dry docks it is, of course, imperative it be in some protected harbour, and it is best to select a site in the harbour's most sheltered part, so that the docking of large ships may not be interfered with by heavy gales and rough seas.

Next, it is quite necessary that the site be composed of comparatively low and level ground, in order that the land approaches may be favourable. Then the shore should be quite abrupt and the water of a good depth, so that the sea-approach may be as short as possible.

For purposes of construction it is desirable that the sea be not too deep, and it is also very desirable that the bottom be bedded in a good coat of sand or mud, in order to facilitate the construction of the coffer dam that is always necessary to build as one of the preliminaries to the dock construction.

The excavation for the basin that is to form the body of the dock and the construction of the coffer dam may be commenced simultaneously, if so desired, for a rim of the original shore may be left standing until the main bulk of the excavation has been done, in order to keep out the inflow of the sea.

Then as soon as the coffer dam has been completed a set of great pumps are put in operation to empty the space enclosed within the dam, and when this has been accomplished the rim of earth intervening between the coffer dam and the landward excavation may be dug out and the work of constructing both the body of the dock and the gate seat prosecuted.

These coffer dams are constructed of sheet piling, or piling composed of tongued and grooved planks, so that the dam, when finished, may be water-tight. A mud bottom into which to drive this piling largely facilitates construction, as well as insuring a more impervious dam.

As has been intimated, the most desirable earth substance in which to build a dry dock is a rock formation, because when the excavation has been finished the rock face of the basin thus formed affords a most substantial basis for both the bottom and sides of the proposed dock.

The sides of the dock are made sloping, so as to conform somewhat to the shape of a ship's hull; but the floor is quite broad and level, and the breadth is given in order to make room for the manipulation of the bilge-blocks, or the blocks that are designed to stay the sides of the hull while the ship remains in the dock, as well as to make room for the staging upon which the men engaged in the work of renovation are to stand.

The seaward end of the dock is made square, while the landward extremity has a tapering form with a rounded point, which also conform somewhat to the shape of a vessel's prow.

The interior facing of a dry dock may be of wood, stone or reinforced concrete; but the last-named material is the most popular at the present day. The floor, however, is covered with cedar planking.

The gate and gate-seat of a modern dry dock are important adjuncts, inasmuch as they must have the requisite strength to withstand the pressure of the sea so soon as the dock has received a ship and has been pumped out.

The gate-seat is built of dimension granite and the approaches of concrete. The gate itself is simply a wood or steel caisson, shaped very much like the hull of an ordinary vessel, excepting that it has a sharp peak at both ends.

The caisson of the proposed mammoth dock at Hunter's Point, San Francisco Bay, will be of steel, 147 feet long at the deck, 128 feet long on the keel, and will have a depth, from deck to bottom, of 41 feet; the width of beam will be 26 feet.

The operation of docking, while comparatively simple in theory, requires much care and judgment. The vessel to be repaired or cleaned is towed to the entrance and hauled carefully from that point into the dock by hawsers operated by power capstans placed along the dock walls. After the vessel is in position, the caisson which forms the entrance gate is floated into place and its filling valves opened, allowing it to settle into the grooves in the entrance walls. After the dock is thus properly closed the pumps are started, and the water level is lowered, permitting the vessel to settle upon the supports provided for it.

This foundation consists of a row of keelson blocks running through the centre of the dock longitudinally and two rows of bilge blocks, one on each side of the dock, these blocks having been placed in exact position before the filling of the dock with water previous to hauling in the ship, and they are held in place by ironed bilge ways, which are gripped by clamps attached to the bilge blocks.

The dock having now been pumped out and the floor cleaned by scrapers, the dock is ready for the workmen's staging, and as soon as this is in readiness the work of overhauling the hull may proceed.

The placing of the bilge blocks

previous to the filling of the dock with water is a very particular job, for when the water is pumped out after the vessel has been drawn in, the vessel must be made to sink and rest upon its foundation evenly in every part, in order to prevent any possible strain upon the hull.

In order that this may be accomplished, the master of any vessel that may be awaiting admission to a dry dock is required to furnish the manager of the dock with drawings, giving the exact contour of the vessel's hull, in order that the bilge blocks may be placed in an exact position to receive the burden they are about to have placed upon them evenly.

When the repairs of a ship have all been finished and the vessel is ready to leave the dock, the filling valves on the inside of the gate are opened and the water let in until the dock is full again.

Then the filling valves on both sides of the caisson are closed and the water pumped out, and when all is out the caisson floats again and may be towed away, and then the renovated vessel comes out of the dock and is ready for another voyage.

PROFIT SHARING

By A. Wilson

A VAST majority of the trade disputes between capital and labour, which are of almost daily occurrence throughout the country, originate from differences of opinion between employers and employees as to the rate of wages to be paid to the latter. Other questions, connected mainly with working conditions, do occasionally arise; but the remuneration to be given and received in return for labour always has been the chief source of disagreement.

That this is natural, is readily understood, if we regard employer and employee as buyer and seller, respectively, of a commodity—in this instance labour. The one, in the case of a manufacturing concern, purchases his labour, as also his raw materials, as cheaply as possible, and resells these, in the form of finished goods, at the highest obtainable price, the difference between his receipts and his expenses representing the profits of the business. The other, like all vendors of material goods, naturally desires as large a price for his commodity as the state of the market and his power of bargaining permit. Either of the parties to the transaction has every right to decline business should the terms offered by the other appear unprofitable or unfair, having regard to the existing conditions of trade.

When this happens, if the manufacturer is unable to obtain labour from other sources at his own terms, or if the operative fails to obtain remunerative employment in other works—as may, and does, happen in the case of a factory isolated from its kind and dependent on a supply of labour of a peculiarly skilled nature—the operation of the factory ceases until one side or the other concedes the terms demanded or a compromise is mutually agreed upon. In the interval, on both sides there has been a stoppage of earning power, and consequently of income.

Nor does the damage end here. The manufacturer, unable to fulfill his contracts or to respond to the demand for his finished goods, finds that his customers are driven to obtain their supplies in other markets, and the business connections which he has succeeded, it may be with great difficulty, in establishing are lost, perhaps never to be regained. Not only so, but, although the factory may be at a standstill, it is still a source of expenditure; for what may be termed establishment charges, such as salaries of superintendents and clerical staff, rents, rates, insurance, and the like, are often a considerable proportion of the total working expenses, still run on, and have to be met without any corresponding receipts. On the other hand, the workman, deprived of his weekly wage, has to expend for the maintenance of himself and his dependents the funds which he has been able to lay by, whether these exist in the form of cash savings or of strike allowances drawn from the funds which he has periodically contributed to his union. And not infrequently he finds, as does his employer, that the market for his labour has been driven to other localities or irretrievably destroyed.

It appears to the writer, who has occupied the position both of employee and employer, that such de-

plorable results might, in many cases, be avoided if it were more clearly and generally recognized that the interests of the two classes are, to a large extent, identical rather than antagonistic. Too often does the master regard his men as mere machines, to be driven at the highest possible rate at a minimum of cost. As often does the man look at his employer as a taskmaster from whom the greatest possible amount of money is to be extracted in return for service grudgingly rendered. From individual cases of such antagonism there have been developed wholesale divisions between capital and labour, till we find in almost every trade combinations of masters and men, respectively, banded together for the sole purpose of defense against the encroachment and demands of one another.

There are, of course, many exceptions in the industrial world to such a state of matters, cases where masters and men, recognizing that they are largely dependent on one another for prosperity, are able, solely through the exercise of common sense and fair dealing, by reasonable and timely concession on either side, to work together for years, in times of prosperity and in the more trying periods of trade depression, with nothing but friendly relations and no suggestion of lockout or strike. The factors contributing to these happy conditions are, however, of a more or less abstract nature and, with the increasing tendency toward combination both of masters and of men, instead of both parties acknowledging that their existence rests largely on the skillful and continuous prosecution of their trade, they face one another with feelings of jealousy and suspicion, which are too often regarded as perfectly natural.

As already mentioned, the chief point on which differences arise is the question of remuneration. When trade is brisk and the employer has secured an ample supply of orders, it frequently happens that the operatives consider that they are entitled to participate in the general prosperity in the form of an increased rate of wages. On the other hand, when trade is depressed and difficulty is experienced in booking orders at remunerative rates, the employer naturally attempts to reduce the cost of production, and is often able to do so only by a reduction in wages. Neglecting other less prominent causes of friction, it will be admitted that the adoption of a system which would automatically adjust the question of remuneration between the employer and his men ought, by removing the cause of disagreement, to enhance the stability of the trade and the welfare of all engaged in it; and if such a system should have this effect, amongst others, of reducing working costs and at the same time adding to the earnings of the men, its acceptability to both sides should be without question. Such results can be, and are, being realized by what may generally be termed profit-sharing schemes, such as are being increasingly adopted by many concerns in the manufacturing world.

Broadly speaking, all profit-sharing schemes are based on the payment by the employer of a standard wage to his men, and, in addition, the handing over to the latter of further additional payments, the amounts depending on the skill and diligence with which the work is carried out, the saving or profit thus effected being shared in some fixed proportion between employer and employees. In different trades such schemes vary considerably as to details, according to the nature of the manufacturing operations, but for purposes of explanation they may be divided into two general classes, viz., premium systems and the more general bonus systems.

The premium system will, perhaps, be more clearly understood by reference to a concrete example. Take the case of an engineering business devoted to the construction of a special class of machinery. The

component parts of a machine are finished and ready to be put together to form a complete machine. From previous experience of similar work, the manufacturer has arrived at the time occupied by the average workman in carrying out this operation. Let it be assumed that in this case the time amounts to six hours. Under the premium system the mechanic, working at his standard rate of pay, is informed that the time allowed for the operation is six hours, but that, if he can complete his task in less time, he will not only be paid his ordinary wages for the time thus occupied, but, in addition, will receive pay for, let us say, half the time he saves. With this incentive, he applies himself diligently and intelligently to his task and succeeds in completing it in four hours. What is the result? With a standard rate of 8*d.* per hour, he receives for four hours' work the sum of 32*d.*, or 2*s.* 8*d.*, and, in addition, as a reward for his increased application, or skill, a premium of one hour's pay, namely, 8*d.*, or in all, 40*d.*; or to look at it in another way, his rate of pay has been raised to 10*d.* per hour. From the employer's point of view there is also a decided gain. What originally cost him 48*d.* has now been produced for 40*d.*, and he is enabled to sell goods at a correspondingly greater profit, or to reduce his selling price with a view to obtaining a greater number of orders. Not only so, but two hours have been redeemed, which may be employed in further useful work, the output of the factory and, therefore, its profit-earning capacity, being proportionately increased.

On both sides, therefore, there is a positive gain. Nor is the employer disposed to grudge the higher wages he pays, for his costs decrease in proportion as his wages bill rises. The workman, on his side, is encouraged to apply his energy and his intelligence towards performing his duties in the simplest and most economical method, conscious that such efforts will be proportionately rewarded.

The particular advantages of the premium system are that the payments are directly proportional to the improvement in results, that individual effort is specially encouraged and directly rewarded. From accounts which have, from time to time, been published of actual results obtained by the introduction of this system, many striking examples might be instanced. The experience of one engineering firm through a period of five years may be quoted. The head of the firm, one of the first, if we mistake not, to adopt the system in England, in a paper on the subject states "that when the men were put on the premium system after they had been working on time, they would, through their own exertions or skill, and without any change in conditions, reduce the time on an average by 15 per cent."

In many trades, however, where standard or repetition work is infrequent, where the nature of the operation varies so much from time to time that it is impossible to apply past experience in determining the time to be allowed for future work, the premium system, as above exemplified, is applicable only to a limited extent, or even not at all. In such cases a bonus system may be advantageously adopted, either alone or in conjunction with the premium system.

In such a case the employer, instead of paying on the results of individual operations, agrees to distribute amongst his employees a fixed proportion of the general profits of the business, as determined by his periodical balance sheets, the intention being, as before, to promote increased efficiency of labour and to reward the same in proportion to the results obtained. The following particulars may serve to explain how such a system may be applied, and are taken from a scheme in actual operation:

The amount to be paid to the employees is a fixed percentage of the net profits, and to obviate any sus-

picion of unfair dealing this percentage has been communicated in writing to an independent accountant, who, from an inspection of the balance sheet and other relative documents, certifies after each balance the amount due to each workman. Those of the employees who are entitled to participate in the profits are limited by certain conditions. They must, for instance, have been at least one year in the employment of the firm, so that casual or temporary hands do not, for obvious reasons, participate. The amount due to each individual is proportionate to the rate of wages he has received during the current year, and depends also on the number of hours worked. This latter condition is directed towards encouraging good time-keeping habits, and as a further inducement it is enacted that, if any one loses more than a certain number of hours in each fortnight, none of the time worked during that period may count in calculating his actual bonus. It should be noted that the result of this rule is not to reduce the total amount paid to the employees, but to distribute amongst the steadier workmen what has been lost by the man of irregular habits, so that diligence is, as it should be, rewarded at the expense of sloth. The actual distribution of profits takes place as soon as possible after the completion of the balance sheet, and the various sums may be at once withdrawn in cash or left on deposit with the firm, interest being paid on any such balance at the rate of 4 per cent. per annum. Further, these deposits may be withdrawn at any time or may be increased by further sums not necessarily received in the form of bonus, interest being paid on the total amounts on deposit as already indicated. The foregoing are the general outlines of a profit-sharing scheme which, with modifications in details, might be applied to various kinds of trades.

Profit-sharing in this way possesses several disadvantages as compared with the premium system. Individual effort is not so directly rewarded, for the loafer, if he keeps good time, as surely obtains his bonus as the diligent and skillful workman, while the loss due to his waste of time is distributed over the whole body of profit-sharers instead of reacting directly on the author of it. Payment of the profits is made at long intervals—it may be half-yearly or even yearly—and the advantages of increased application are not punctuated so sharply as when premiums are paid within a week or so after they have been earned. To the employer the resultant gain does not appear in black and white, as with the premium system. On the other hand, as the payments depend directly on profits, should these be unduly small or non-existent, the bonus payments are proportionately reduced, whereas with the premium system it is within the grounds of possibility that a profitless balance sheet might be experienced at the end of a year's work, although during the same period a large amount had been paid away as premiums to the employees.

As regards the actual monetary gain to the workers, in the case cited we find that, taking the averages over a period of six years, thirty-five individuals, comprising mechanics, apprentices, drawing offices and clerical staff, had their wages increased 5 per cent., varying with the prosperity of the business from 3 per cent. minimum to $7\frac{1}{2}$ per cent. maximum. In addition, interest was paid annually on an average sum of £82, left on deposit with the firm, the actual total of the deposits varying considerably at times above and below the average. Unfortunately, the advantage gained by the employers cannot be stated in figures in the same way, but that there is a considerable advantage is undoubted. The general and spontaneous application of the men to their work is evident, although not always to be gauged by actual hours saved. A better class

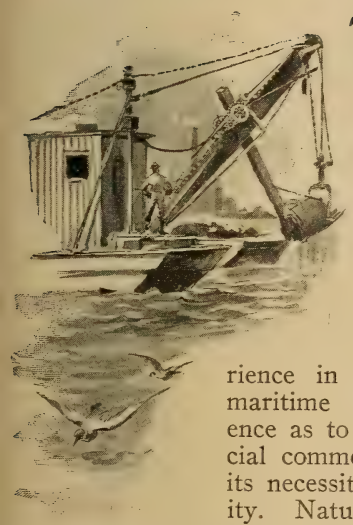
of man is attracted to the factory and retained there, even although higher wages might sometimes be obtained elsewhere. Greater care is taken of tools. Waste of material, often the source of considerable loss to the employer, is reduced. A more general desire to carry out the work promptly and thoroughly is evinced, and the result, as evidenced by the satisfaction of customers, is to bring more grist to the mill. An *esprit de corps* obtains in the community, special demands for extra exertion and hard work in times of emergency are willingly responded to and, generally, the feeling which is instilled in the minds of the men that, in working for their employer, they are also advancing their own personal interests, makes definitely, if somewhat intangibly, for efficiency and economy.

Undoubtedly payment by immediate result is the more scientific and precise method of profit-sharing, but where this is impracticable for the reasons mentioned the more general system just described may be introduced with undoubted benefit to all concerned.

Industrial competition becomes every day more and more severe, the struggle for existence driving manufacturers to run their factories at the highest possible efficiency. While, no doubt, standardization of work and improved machinery and methods are the chief factors of successful production, it is suggested that profit-sharing in one form or another will be found to offer a not unimportant auxiliary towards attaining the end for which an engineering works is operated.

SUBAQUEOUS ROCK REMOVAL

By Brysson Cunningham



THE deepening of river beds and of harbour entrance channels has become, of late years, a matter of such common occurrence and of such everyday experience in the practice of maritime engineering science as to call for no special comment in regard to its necessity and universality. Natural facilities are now, in so many cases, no longer adequate for the needs of modern steamships in their arrival and departure from commercial ports, that recourse has continually to be had to artificial means for providing additional depths in fairway and channel to meet these exigencies imposed by the vigorous law of progress and development.

The material met with in the course of deepening operations is, as might readily be expected, of an extremely varied and heterogeneous character. Mud, sand, silt and other soft, light deposits generally overlie more substantial beds of clay and marl, while in other localities the strata are of an even more indurated class, comprising all kinds of conglomerate, poach and shale, and culminating oftentimes in the hardest and most impenetrable varieties of rock.

With the appliances and processes necessary for the removal of the softer kinds of earth we are not immediately concerned. We have, in fact, already considered them pretty fully in two articles which appeared in this magazine in November and December, 1905. Our present purpose is to confine our attention to the least tractable class of material, and to describe the methods available for the subaqueous removal of rock.

The word rock is, indeed, a somewhat comprehensive term, and includes a good deal of miscellaneous material, ranging from readily friable and porous sandstone to the most adamantine and impervious trap and granite. There is almost as much diversity among the different varieties of rock as there is between rock and other earths. We will not, however, waste any time over unnecessary technical distinctions, merely indicating that rock will here be used in its commonly accepted sense as a material of considerable hardness and compactness, without any precise limitations as to its nature and composition.

At the present time there are in vogue three systems of subaqueous rock removal.

The first is that of dredging, pure and simple. Naturally, it will be seen that the method is only applicable to the softer varieties of rock, and that it has to be carried on by a process of scraping and scratching, rather than of scooping, which is the usual action in connection with material of less resistive powers. The system, therefore, is not of general application, and in any case it is not suitable for very extensive operations; nevertheless, it is useful under certain appropriate and favourable conditions.

Dredgers for rock work are of the

ROCK DREDGER "STONEWALL," BUILT BY MESSRS. W. SIMON & CO., RENFREW

bucket type, working on an endless chain, and from the arduous character of their functions it is evident that there must be very severe wear and tear on the bucket-lips, as well as upon the driving machinery, which obviously entails considerable expenditure on maintenance and repairs. The bucket-lips have to be constructed of specially hard steel, and very often they are fortified by a row of spikes, or tynes, along the cutting edge, and it is by no means unusual to find tyne frames or nipping claws alternating with buckets. Despite these precautions, the necessity for renewals and repair is always existent, and constitutes a current charge. The output, moreover, of dredgers engaged on this class of work is never anything but meagre, and the cost is correspondingly high, especially where there is added thereto the incidental expenses mentioned above, and the allowances due for interest and depreciation. It is, in fact, within the writer's knowledge that rock dredging in soft sandstone has cost from six to ten shillings a cubic yard, or at least three or four times as much as bucket dredging in ordinarily firm ground. Added to this there is the tedious nature of the process, and also the slow progress made, so that the result is not generally satisfactory. There must, in fact, be special circumstances calling for this method of treatment in order to justify its adoption.

An obvious means of improvement is to prepare the rock beforehand, so as to render its removal an easier process. This can be done in alternative ways, viz., (1) by drilling and blasting, and (2) by cutting and pulverizing. These constitute the second and third systems of rock dredging previously alluded to, and, in contradistinction to the first system, they are applicable to all kinds of rock.

Drilling and blasting is a costly operation, and it is slow, especially in dealing with very hard material. A barge is employed, fitted up with a number of drills. These last usually work in tubes resting on the surface of the rock, so as to prevent mud,

silt and débris from drifting into and choking the bore holes. The tubes also afford the necessary guidance and direction. The drills are worked by ropes passing over pulleys on a driving shaft, each drill being under the control of one man, who alternately tightens and slackens his hold as the shaft revolves. After the holes have been drilled to the required depth, the services of a diver are requisitioned to insert the cartridges, which are subsequently exploded. Then the débris is removed by means of grabs or bucket dredgers.

The cost of drilling holes in sandstone rock proved, in one case within the writer's experience, to be thirteen shillings per hole, 6 feet deep. The holes were within a restricted area in a narrow waterway, where the work was subjected to interruptions, owing to the necessity of passing vessels through. These conditions militated against economy. There can be little doubt that under favourable circumstances the cost per hole would not have exceeded ten shillings, and this would have brought the charge for drilling and blasting to rather less than two shillings per cubic yard of material removed, or say four shillings to four shillings and sixpence per cubic yard, including the cost of dredging, but not of interest and depreciation charges on plant.

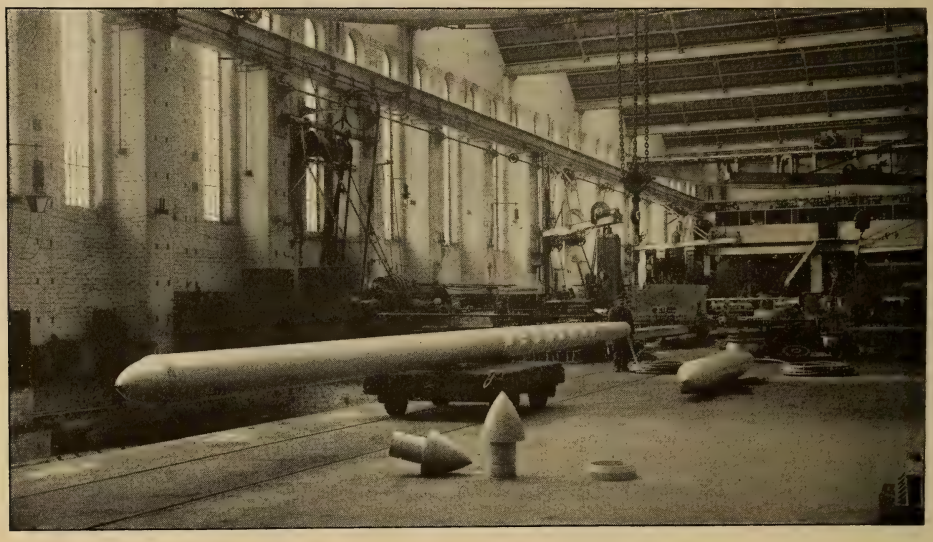
The holes are spaced 5 feet apart. In another instance in the same locality and in rock of the same character, where the holes were spaced 4 feet apart and drilled to a depth of 16 feet, the expenditure worked out to about 3/3d. per cubic yard for drilling and blasting alone. It does not appear from this example, therefore, that deep holes are attended by economical advantages. Indeed, from the necessity of employing heavy explosive charges, there is some consequent risk of the resultant débris being too large for removal by dredging without further treatment. The cost of three shillings per cubic yard is, however, not exceptional for this class of work and,

A LOBNITZ ROCK CUTTER AT WORK AT BLYTH

indeed, represents the figure given by Mr. Sandeman for operations in the coal measures* sandstone at Blyth. The writer is aware of other cases where figures of from six to ten shillings per cubic yard, inclusive of the cost of dredging, have been attained. The cost of dredging is, unfortunately, not separable in these cases, and, therefore, it is not possible to make very effective use of the figures in comparison with the preceding, though it is probable the former are higher.

The third system, or rock breaking by means of a heavy pick or cutter, has been very successfully developed of late years, and bids fair to become generally adopted in all future operations of any magnitude. The principle is that of allowing a heavy shaft, or ram, with a hard, pointed end, to fall upon the surface of the rock, the blows being repeated until the rock is pulverized and broken to the required level. This system, though undoubtedly first introduced into maritime work forty years ago at the port of Cette, has only within a comparatively re-recent period received the attention which it merits; but it has latterly been very enterprisingly developed and improved at the hands of Messrs. Lobnitz & Co., of Renfrew, who have made it a specialty.

At first the rams were comparatively light, not more than 5 tons, and they had to be given a considerable fall (20 feet or so) in order to produce any appreciable effect. In the latest type of appliance, rams weighing 15 tons and upwards have been employed, with a fall ranging from 5 to 10 feet. It is interesting to note that the mere statical pressure of a ram of 15 tons weight (13 tons in water) bearing upon a point of one centimetre area is five times the limit of resistance of the hardest rock, and when the ram falls through a height of 10 feet the accumulated energy on the point is twenty-three times the average energy accumulated per square centimetre of the section of a shell issuing from the most powerful gun existing.†

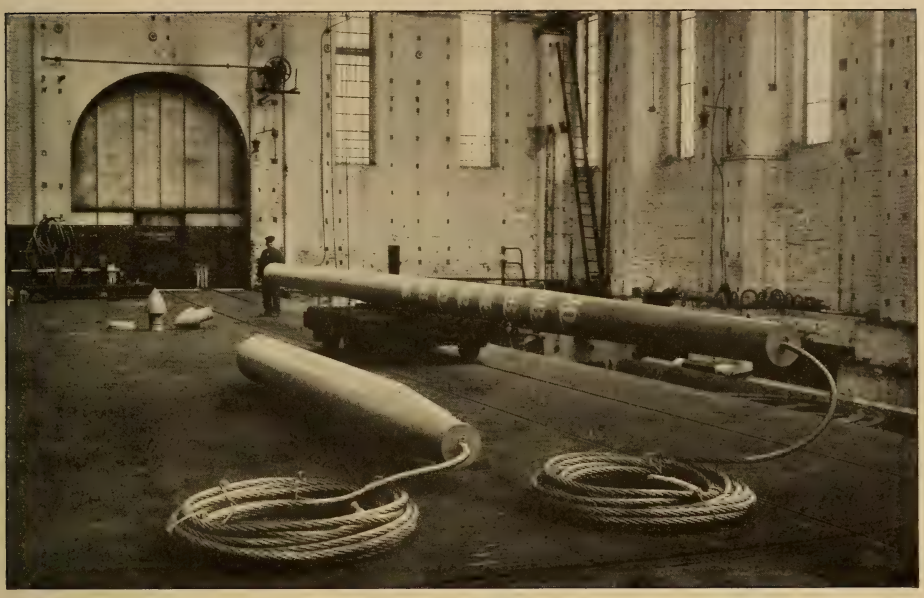


THE COMPLETE RAM OF THE LOBNITZ ROCK CUTTER

Although it must be freely conceded that the energy of a 5-ton ram falling through 20 feet is theoretically the same as that of a 20-ton ram falling through 5 feet, yet the practical results are different. The heavier ram with the shorter fall

* Eng. Conf., 1907.

† Mr. Bunau Varilla at the Eng. Conf., 1907.



LOBNITZ ROCK CUTTERS, SHOWING DETACHABLE POINTS AND SUSPENSION ROPE

has proved itself the more effective; there is more pulverization and less fissuring. The débris, in short, is produced in a better form for removal by dredging. Of course, in rock of a light character and in shallow water, where there is less frictional resistance, it is unnecessary to use very heavy rams, and rams of 6, 5 and 4 tons are in common service for the lighter classes of rock.

Rams are now generally made to a standard weight of 1 ton per metre, so that a 15-ton ram indicates a length of approximately 50 feet. The heaviest ram stated to have been employed up to the present time has weighed 20 tons; but there is no apparent reason why so great a weight as this should not be exceeded where circumstances permit of the advantageous employment of the increased inertia.

The nature of the point, or cutter, is a very important consideration in regard to effective work. It is detachable from the shaft, and is made of a special quality of forged steel adapted to the particular variety of rock which is to be dealt with. It is not by any means a necessary conclusion that the harder the rock, the harder the steel. In rocks of great hardness, such as granite, a tough steel is the greater desideratum, while a hard steel may be used very effectively in friable sandstone. In any case, the cutters are made harder in the interior than on the surface, so as to maintain a sharp point under wear.

The cutters, as a rule, are worked by a wire rope (not chain) from a steel framework, of tripod form, arranged on the decks of barges, and in some cases several cutters are fitted to a single barge at distances of about a yard apart. The single cutter has been found to be the preferable system, and rarely more than three cutters are grouped together now, though formerly as many as ten have been worked from one barge.

The pitch, or distance apart, of the holes is more or less a matter of practical experience on the site; but, generally speaking, it ranges from 2 feet to 6 inches in granite to 3 and 4 feet in sandstone. The number of blows required to produce disintegration is also a matter of experiment,

and it can only be said, as a rough guide, that in average material some 2 cubic feet per blow may be reckoned upon.

The question of cost naturally arises for the purpose of comparison with the preceding systems. It is very much less than either of them, as will be evident from the following figures:

During five months' operation on a portion of the sandstone bed of the River Mersey opposite Tranmere, 11,415 cubic yards of rock were broken, at an average cost of 11.81d. per cubic yard, excluding insurance, establishment charges, interest on capital and depreciation.[1]

A week's work of one cutter on the sandstone at Blyth was 908 cubic yards, at a cost of 8.8d. per cubic yard, which, however, did not include renewal of rams. Allowing for these and other repairs, and everything except insurance, establishment charges, interest and depreciation, as before, the average cost was 11.79d.,[2] which agrees remarkably closely with the preceding example.

Mr. W. H. Hunter, the engineer to the Manchester Ship Canal Company, has stated even better results than these from operations in the saliferous marl of Cheshire. Over a period of ten months, the average quantity of rock broken per month was 6,403 cubic yards, at an average cost of 8.94d. per cubic yard,[3] a figure which includes repairs and renewals, and is, in fact, comparable with the unit costs quoted above. At the Engineering Conference held in London last year, he went further and stated that the actual cost of rock breaking during one month was only 5.39d. per cubic yard, which indicates a very high degree of efficiency indeed in the plant employed, though, of course, the large quantity dealt with (17,400 cubic yards) and the extensive nature of the operations were influential factors.

The cost of rock breaking in the Suez Canal, where the material is of a very varied character, consisting of limestone, more or less hard; calcareous and silicious agglomerates, calcareous tufa, gypsum and alabaster, ranged from 2.26d. per cubic yard up to 7s. 6.57d. and averaged 1s. 4.1d. per cubic yard.[4]

The cost of removal has not been included in the foregoing statistics, in order to simplify comparison, and because the conditions of conveyance from site are so variable. It may be taken to average about two shillings or half a crown a cubic yard, though it has been done for much less.

From this brief statement of the data furnished by the recent use of the rock-cutting apparatus in various places, it is evident that there is real scope for its future employment and every prospect of its increasing popularity. No port need be deterred by the prohibitive expense which characterized former operations in rock removal from undertaking those steps of deepening and widening in connection with its approach channels, which are so essential to its commercial prosperity and development. No matter how hard and impenetrable the strata forming the beds of rivers and canals, it is always possible to deepen them, and so render them more suitable to the requirements of modern navigation, at a cost not greatly in excess of that which would be entailed by the removal of merely soft earth. And in regard to the formation of new routes for water-borne goods, the principle of dredging is one which now offers in all kinds of material such decided economical advantages over excavation in the open that it at once commends itself for adoption generally.

[1]Williams on Rock Breaking Min. Proc. L. E. S., Vol. XXVIII., p. 122.

[2]Sandeman on Rock Removal at Blyth. Eng. Conf., 1907.

[3]Engineering, Aug. 17, 1906.

[4]Quellence on Dredging Rock in Suez Canal. Eng. Conf., 1907.

THE MINING ROYALTY BURDEN ON BRITISH IRON AND STEEL

By T. Good

IN the November, 1905, issue of this magazine we called attention to the serious nature of the mining royalty burden on our iron and steel industry. Opinion on this question has ripened since then, and we are advised that the matter is shortly to be raised in Parliament, so that we need offer little apology for returning to the subject just now—a subject which vitally affects not only the production of coal and iron ore, but the manufacture of iron and steel, and is, therefore, of special interest to our readers.

We may be permitted to recall that, in the article alluded to, we stated that mining royalties represented a tax of not less than one shilling per ton of coal raised; that this was, in turn, a tax on the general industry of Great Britain, and especially upon the steel trades in which so many tons of coal are used, in the manufacture of a single ton of finished goods; and we argued that these mining royalties tended to handicap us in competition with our foreign rivals. That is the point we now wish to make clear to those who imagine that this mining royalty question is of little account. At the present moment foreign competition is not keen, but the day may not be far distant when production of iron and steel in other countries may largely exceed consumption, and our industries may then be involved in another severe struggle. For that reason we would do well to give the earliest possible attention to any unjust burden we labour under. And none are more unjust, in the writer's opinion, than that of mining royalties.

Interrogated on this question by Mr. Markham, M. P., the Prime Minister denied that further inquiry was necessary, and stated that the government already had enough information on the matter from the report of the Royal Commission on Mining Royalties. We respectfully suggest that there are good reasons for not agreeing with the Prime Minister. In the first place, we may point out that the report of the Royal Commission was based upon inadequate information. Secondly, the commissioners either ignored or underestimated some important points in such evidence as was given. Thirdly, some material changes have taken place since 1889—the year upon which the report was founded—changes which have rendered the problem far more urgent than formerly.

The Royal Commission on Mining Royalties estimated that in 1889 the average royalty on coal was about 5¾*d.* per ton, and on iron ore about 9*d.* per ton. But it is not true that that estimate is anywhere near the mark now. Nor was it strictly accurate at that time. We are justified in putting in our own estimate of 1*s.* per ton of coal and iron ore raised and 6*s.* per ton of pig-iron produced—that is, in shape of royalties on ore, limestone and coal used in making a ton of British pig-iron. And this pig-iron, with this tax, is but raw material for our steelmakers and engineers, as further quantities of coal, bearing royalty, have to be consumed in working it up into finished articles.

Starting with the 5¾*d.* per ton estimated by the Royal Commissioners as being the average royalty burden

on coal in 1889, we find that coal prices have been much higher in recent years than they were in that particular year, and as royalties are in many cases based on a "sliding scale" principle, it is safe to say, from the calculations of the Royal Commission, that since 1900 royalties will have averaged between 7*d*. and 8*d*. per ton. But we have to remind those interested that several royalty charges which are levied upon our minerals—lease fees, waterleaves, airleaves, etc.—were either totally ignored or palpably underrated by the Royal Commissioners when calculating their estimate. In fact, the commissioners themselves admitted that their report was based on "meagre" information, many tenants being reluctant to give full accounts as to the exactions imposed by their landlords. Then again, not only have we substantial proof that the estimate of 5¾*d*. per ton was below the actual mark in 1889,* and that even on that basis the burden will now reach between 7*d*. and 8*d*., but we have evidence that royalties upon coal which has been leased, or of which the leases have been renewed in recent years, have been fixed at a much higher rate, in many cases, than obtained previously. Mr. D. A. Thomas tells us that, in the case of Welsh coal, royalties have been put up by "several pence per ton." What applies to Wales undoubtedly applies to other portions of the Kingdom. Besides, we know of mining companies paying 1*s*., 1*s*. 4*d*., 1*s*. 6*d*. and even 3*s*. 6*d*. per ton of coal, and iron ore raised in royalties to their landlords. We adhere to our estimate of an average of 1*s*. per ton of raw mineral raised, and contend that this is an unjustifiable tax on British industry.

To illustrate how these royalties are liable to affect British firms in competition with, say, Germany, we may quote a case that occurred recently in which a Yorkshire firm was in competition with a German firm for an order to supply steel rails to a south-of-England corporation. The Yorkshire firm use Lincolnshire or Northamptonshire ironstone, upon which royalties are from 1*s*. to 1*s*. 6*d*. per ton. It takes four tons of this ironstone to make a ton of rails. This means a royalty charge of from 4*s*. to 6*s*. per ton of rails for ironstone alone. To manufacture this ton of rails there are used 3½ tons of coal. In Yorkshire coal royalties will now average 1*s*. per ton. This adds another 3*s*. 6*d*. to the cost of producing a ton of rails, and if we reckon another 6*d*. per ton in royalties on limestone, etc., we arrive at a total royalty charge upon our steel rails somewhere between 8*s*. and 10*s*. per ton. Such charges in Germany would not exceed 1*s*. per ton. If to this fact we add the further circumstance that the Germans can send their rails to an English port at much less cost of carriage than the Yorkshire firm can, we need not wonder at the growth of German rivalry in recent years. And we may mention, incidentally, that the primary reason why cost of carriage is so much higher in this than in other countries is because of the same land system, which is responsible for our mining royalties being so oppressive. The fact is, that the British landowner enjoys almost unlimited liberty, which he frequently abuses, to the detriment, and at the expense, of British industry. We are not discussing this matter as a political question, but as an industrial question, and one which must be tackled. Not only have our landowners charged extravagant prices for land needed for railways—prices which are reflected in high transit rates—but they are permitted to charge just what they like for the minerals which Nature has deposited under the land they happen to hold. This burden of mining royalties was bad enough when we had no formidable rivals in manufactures; but now that we have

* The late C. M. Percy, of Wigan, an undoubted authority, put coal royalties at 8d., and ironstone royalties at 1/, twenty years ago. Sir Isaac Lowthian-Bell and other experts agreed with those estimates.

to meet strong and alert competitors, enjoying much better conditions than we do, the burden must be lightened.

The whole system of granting mining leases in this country is fundamentally wrong and extremely unjust. A mining lease is usually conceded for a term of years—fifteen, twenty-one, thirty or sixty years—the average length of mining leases being estimated at thirty-one years. The terms are mutually arranged between tenant and owner, the State imposing no particular restrictions in the national interest, as is done in Continental countries. A fixed or "dead" rent per acre of coal leased (payable whether the mine proves workable or not), a surface ground rent for the pit-head plant, a royalty per ton of mineral raised, underground and surface wayleaves for conveyance over, under or through ground not included in the fixed rent-bearing leasehold, airleaves for ventilators and waterleaves for drainage purposes are usually stipulated for in the agreement. These charges are generally payable even if, through some unforeseen "faults," the mine turns out unprofitable to the tenants who have risked their capital. In addition to these conditions, a lease fee is sometimes demanded. As much as £25,000 has been demanded for a concession or the renewal of a lease. It is sometimes argued that these terms are fair, inasmuch as they are agreed mutually. Up to a certain point they may be; but the time comes when the lease expires, and the tenant company—their plant in working order and their business established—desire a renewal. This can be obtained only on the landlord's terms, and these are generally unreasonable, frequently exorbitant, and sometimes quite prohibitive. If trade happens to be good, these terms are liable to be based on "boom" figures; then in course of a few years, if trade slackens and prices decline, the company finds itself unable to fulfil obligations, and if the lessor proves ungenerous, the tenants and operatives are turned out, bag and baggage, and the whole plant, machinery and cottages become the property of the landlord. The landowner is in supreme authority in Great Britain, not merely over the land, but over the minerals under the land, and thus controls, unchallenged and unrestrained, the raw materials of industry. All landowners are not stone-hearted; but, taken as a class, they are so human that, being allowed almost unlimited freedom, they impose such exactions upon our industrial development that we are fettered by railway rates twice and thrice as high, and by mining royalties from five to ten times as high as those of competitive countries. We respectfully suggest that, in the interests alike of industry and of the nation, which is dependent upon industry, it is high time for full inquiry into, and effective remedy for, the mining royalty grievance and the system responsible for it.

In conclusion, we may point out that, while in other countries—at any rate, in Continental countries—mining royalties, fixed by the State, are a very moderate charge only on profits actually realized, they are in this country a highly burdensome tax on production—a tax now amounting to fully £13,000,000 annually.

THE NEW BRITISH PATENT ACT

A NOTE ON THE MORE IMPORTANT PROVISIONS

By George Barker, Fellow of the Chartered Institute of Patent Agents

The recent changes in British patent law are of interest and importance to inventors and engineers both in Great Britain and in the United States, since many American inventors seek patents in Great Britain, while British inventors also arrange to exploit their inventions in America. The following abstract of the salient features of the new British patent act will thus be welcome on all parts, covering as it does those points in which the principal changes have been made, and coming from a wholly competent authority on this special subject.—THE EDITOR.

THE New Patent Act, the Patents and Designs (Amendment) Act, 1907, which has been consolidated with the previous Acts, is now in force and, on the whole, should render British patent laws more beneficial to inventors and manufacturers.

The particular feature is the provision dealing with the compulsory working in England of patents worked abroad, and this, it is interesting to note, was the chief cause of the amending Act, as it was very strongly urged in the agitation that preceded the introduction of the bill. The opportunity thus given has been taken to introduce a few good, new provisions dealing with the practice in obtaining patents, and also after the grant, and to make modications of previous provisions, so as to render them more workable and, generally speaking, more satisfactory.

It is not possible to deal in this note with each section of the Act, and we shall, therefore, only call attention to the most important changes.

A very useful section is that dealing with the official investigation into the novelty of invention for which letters patent is sought. As will be remembered, under the Act of 1902, which introduced this investigation, the search extended only to specifications published at the time of application, and a gap was thus left, causing considerable risk to the applicant. The investigation is now extended to specifications of all applications on which the patent, when granted, would bear an earlier date than the case under investigation. This is extremely useful, as it is very frequently the period immediately prior to application, where the risk of anticipation is most pronounced, particularly in subjects receiving at the moment considerable public attention.

This search, it will be noted, however, has not been extended to foreign patent specifications, which would have been advantageous, as of course, an anticipating foreign specification published in the libraries here would damage a British claim. For our part, we should have preferred to see this search embody literature also, and we have, in fact, long advocated this, as anticipations in technical works are repeatedly being turned up against claims. We have not the slightest doubt that this will eventually be followed in the law.

Where the investigation as to novelty ends in the invention comprised in the application being wholly anticipated, the comptroller has now power to refuse the application, whereas previously he could only command a reference to the anticipating specifications.

This is certainly a considerable increase in the comptroller's powers, and has not met with much favour;

it is quite appreciated that, with the present office authorities, there is little to fear; but we must admit that the power might, in some hands, be used to the great disadvantage of trade generally, as valuable inventions may be lost, owing to an official failing to appreciate the value of an addition to a paper anticipation. The re-patenting of an old invention frequently means a decided gain to the country when the case is in the hands of a man with the proper ability and possessing the facilities for marketing. Many a valuable addition to commodities has been made by the resurrecting of an old, dormant invention.

A further provision affecting the application stage is that allowing of the cancellation of the provisional when the invention described in the complete specification differs from that in the provisional, the date, of course, becoming that of the complete application. The advantage of this is simply in the practice for obtaining the grant, as a later section relieves a patent from attack on the ground of disconformity when the invention described in the complete, and which does not conform with that in the provisional, is new. The section of the Act allowing any or all of a number of provisionals for cognate inventions to be included in one complete specification should prove a very great assistance to the safe development of an invention.

The power given to the comptroller to award costs in cases of opposition to the grant of patents will discourage malicious delaying of patent grants by filing practically groundless oppositions, which have frequently been an annoyance and expense to applicants in the past. It is well to note that a new ground of opposition is added to the existing grounds, allowing interested persons opposing when the nature of the invention and the manner it is to be performed are not sufficiently or fairly described in the complete specification. This will call for greater care in drawing and settling specifications.

With patents when granted, and to all those in force, we have new sections dealing with working in Great Britain, marking, additions, and the grounds on which their validity may be impugned.

One bad feature relating to patents after grant is that an application for revocation may be made to the comptroller by any person who would have been entitled to oppose the grant. This can be based on all the grounds of opposition, and is practically an extension of the opposition stage. There can be no doubt that this is open to serious abuse, and may militate most cruelly against the inventor not well endowed with means, as, after all his expense in obtaining grant and in developing his invention, right at the point of success he may be threatened on a trumped-up application, without the means of adequately defending himself. Probably even if he sustained the patent he would be completely crippled.

We then come to the working provision: Where a patent is being worked exclusively or mainly abroad, any person interested may, after four years from the date of the patent, apply to the comptroller for its revocation. It will be well to mention here that, with existing patents which have been in force for four years, twelve months' grace is given from the passing of the Act before an application can be made under this section. Care should, however, be taken by owners of such patents which are being worked abroad that the provision is substantially complied with before August 28 next. An endeavour is made to render the compulsory license provisions (which appertain to patents not worked to a sufficient extent to meet the reasonable requirements of the public) more workable, and to lighten the expense of an application under the clause, by enacting that the Board of Trade refer the application to the court instead of the King in Council.

An innovation which must be kept in mind by manufacturers of patented articles is that of marking, which becomes practically compulsory, as innocent infringers are, under the Act, exempted from damages; under this head it is stated that marking an article with "Patent," or with words to that effect, is not sufficient for the purpose—the number and year of the patent should now be stated. The wording of the section is ambiguous as to its application, but the safest course with existing patents is undoubtedly to mark articles made under these, as well as under patents granted after the Act; this is obviously the only course consistent with the intention of the section to protect innocent infringers.

The introduction of patents of addition in Great Britain will, no doubt, prove popular, particularly as, following other countries where patents of addition are granted, no renewal fees are required to maintain these patents in force.

It is made illegal under the Act to insert in contracts or agreements made after passing of the Act restraining conditions attached to the sale or use of patent articles, such as compelling the purchase from the patentee of parts not subject to the patent. It is further provided that any contract made before the Act which would be illegal under the Act is determinable by either party on giving three months' notice, but in this case fair compensation may have to be paid.

Power is given the comptroller to restore lapsed patents, which proceeding has hitherto required a special Act. With this, proper precautions are taken to ensure the protection of persons who have in the meantime acted on their knowledge that the patent had elapsed, and compensation for tools and other preparations for manufacture may have to be made.

As will be seen, the general trend of the Act as regards patents, with the one exception noted, is good, and designed to simplify the various procedures. There are, further, one or two useful provisions for designs, the principal of which are the extension of copyright from five to ten years, and in some cases to fifteen, and the introduction of a clause for restraining threats of infringement. Threats must now be followed up, as in the case of patents, by action, or the threatener is himself open to an action to recover damages for the threats.

FURNACE-GAS DIAGRAMS

IN the November issue of this magazine there appeared, in connection with the article of M. Leon Greiner upon the subject of the "Utilization of Furnace Gases," a diagram exhibiting the possibilities in the utilization of a ton of coal in the coke oven and blast furnace. This diagram, which appears on page 69 of the current volume, and is reproduced herewith, assumed a metric ton of coal (2,208 pounds), containing 75 per cent. of fixed carbon, 20 per cent. of volatile matter and 5 per cent. of ash, the distribution of the various products being given in the form of a circle, both in percentages and in heat units.

M. Greiner has since prepared another form of diagram, showing the same quantities, but disposed in a manner which, we believe, is more effective, and will be welcomed as a very clear exhibit of the commercial possibilities attainable by the use of modern methods.

For purposes of comparison, we give again the circular diagram of M. Greiner, and from this it will be seen that, by the use of a by-product coke oven, utilizing the excess of coke-oven gas over that required for the operation of coking, there can be derived 135 horse-power in a gas engine.

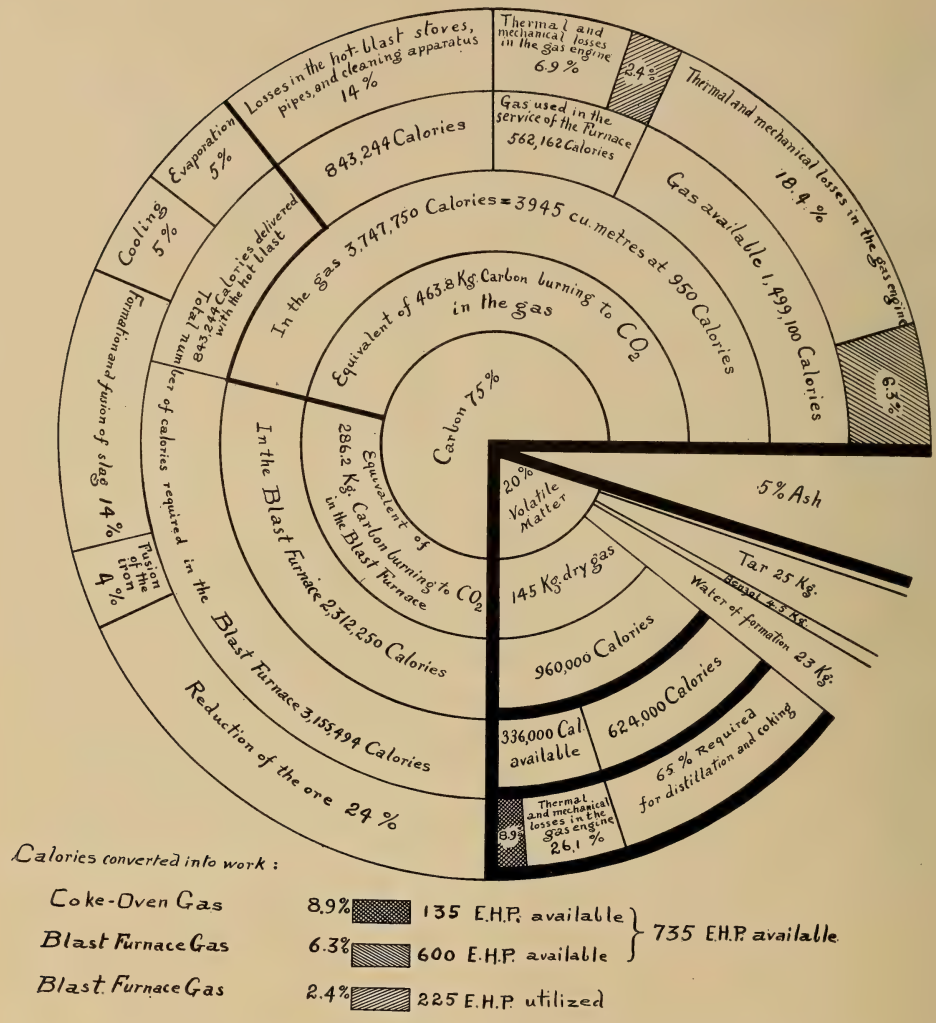
Further, that from the gases discharged by the blast furnace, after the amount necessary for the hot-blast stoves has been withdrawn, there remains sufficient to operate the gas-power blowing engines and the mechanical service of the furnace, and also to drive a gas engine developing 600 additional horse-power. There is thus available 735 horse-power for external uses for every ton of coal required in the manufacture of pig-iron.

The circular diagram, given herewith, takes the 20 per cent. of volatile matter from the coke-oven as producing 145 kilogrammes of dry gas, having a thermal value of 960,000 calories, and distributes it into 624,000 calories consumed by the coke-oven for the distillation and coking of the coal, and 336,000 calories available for the production of power in gas engines.

The distribution of the fixed carbon is also shown as divided between the reduction of the ore and the various transformations and losses in the blast furnace, and in the production of power for the operation of the furnace and for the development of power available for external uses.

Thus, 75 per cent. of the ton of coal, or 750 kilogrammes, evolving 8,080 calories per kilogramme, will produce a total of 6,060,000 calories, of which 2,312,250 are required directly in the reduction of the iron and 3,747,750 are discharged in the gas. Allowing for the portion returned to the furnace in the hot blast, and deducting for the losses in the stoves and in the gas engines, there is developed 225 horse-power for the operation of the blowing engines and for the driving of the lifts and other machinery about the blast furnace, as well as 600 horse-power additional available for other purposes.

In the full-page diagram, given herewith, these operations are shown in a more obvious form. The upper left-hand corner of the diagram represents the coke-oven of the modern


Losses in the hot blast stoves, pipes, and cleaning apparatus 14%
Thermal and mechanical losses in the gas engine 6.9%
2.4%
Thermal and mechanical losses in the gas engine 18.4%
Evaporation 5%
843,294 Calories
Gas used in the service of the Furnace 562,162 Calories
Cooling 5%
Total Therm. 843,294 Calories delivered with the hot blast
In the gas 3,747,750 Calories = 3945 cu. metres at 950 Calories
Gas available 1,499,100 Calories
6.3%
Equivalent of 463.8 Kg. Carbon burning to CO2 in the gas
Carbon 75%
20% Volatile Matter
5% Ash
Tar 25 Kg.
Benzol 2.3 Kg.
Water of formation 23 Kg.
145 Kg. dry gas
960,000 Calories
336,000 Cal available
624,000 Calories
65% Required for distillation and coking
8.9%
Thermal and mechanical losses in the gas engine 26.1%
Formation and fusion of slag 14%
Fusion of the iron 4%
% of calories required in the Blast Furnace
Equivalent of 286.2 Kg. Carbon burning to CO2 in the Blast Furnace
In the Blast Furnace 2,312,250 Calories
In the Blast Furnace 3,155,494 Calories
Reduction of the ore 24%
Calories converted into work :
Coke-Oven Gas 8.9% 135 E.H.P. available
Blast Furnace Gas 6.3% 600 E.H.P. available
735 E.H.P. available
Blast Furnace Gas 2.4% 225 E.H.P. utilized

TOTAL PRODUCTION OF A TON OF COAL IN THE COKE OVEN AND BLAST FURNACE

by-product type, this being the portion of the plant where the volatile matter is separated from the solid carbon. This volatile material, passing through the by-product recovery apparatus, produces 25 kilogrammes of tar, 4.5 kilogrammes of benzol and 2.5 kilogrammes of ammonia, capable of producing 9.7 kilogrammes of sulphate of ammonia, these by-products all having a market value. A portion of the dry gas is shown as being returned to the oven for the purpose of distilling the volatile matter and coking the coal, and the loss in this operation is also shown. Beneath this part of the diagram is shown the gas engine and electrical generating set for the utilization of the gas which would otherwise be wasted, this also in practice generally forming a separate power plant from that using the blast-furnace gases. Of the total heat in the coke-oven gas, 25 per cent. is required for the operations of coking and 40 per cent. is lost by radiation and other causes unavoidable in the conduct of the oven, leaving 35 per cent. of the heat value of the coke-

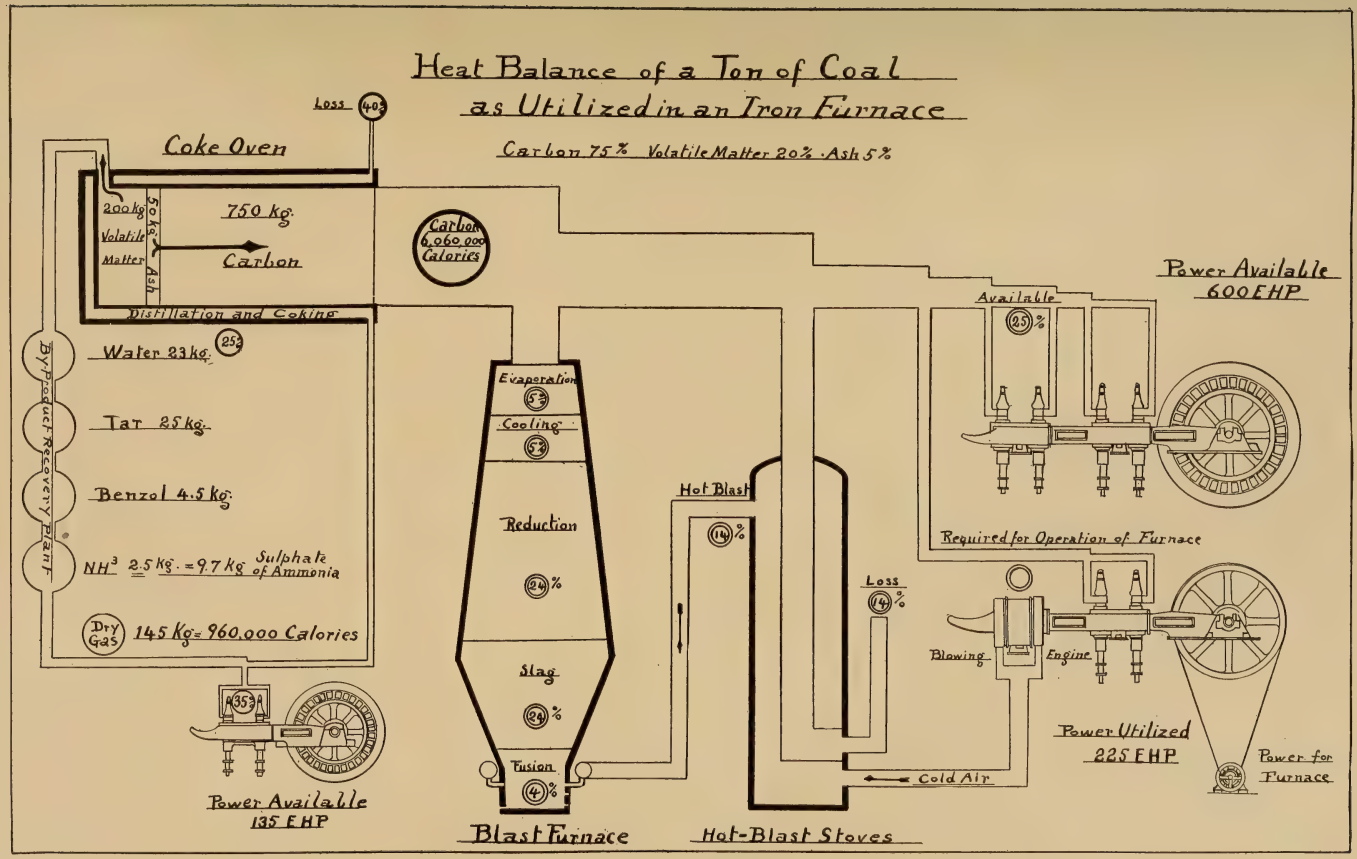


DIAGRAM SHOWING THE POSSIBLE UTILIZATION OF A TON OF COAL IN THE COKE OVEN, BLAST FURNACE, AND GAS ENGINE

oven gas available for power purposes, this corresponding, as shown in the diagram, to 135 horse-power for every ton of coal coked.

The fixed carbon, amounting to 75 per cent. of the original ton of coal, goes to the blast furnace, where it is consumed in the reduction of the iron ore, the combustion giving out gas equivalent to 2,908,800 calories, the balance being utilized in the operations of reduction, fusion and metallurgical effects. Of the 2,908,800 calories not converted in the blast furnace, 1,499,100 calories are available for external power, this corresponding to 600 horse-power, while 843,244 calories go to the hot blast stoves, and 562,162 calories are used in the operation of the blowing engines and the driving of the furnace machinery. The actual reactions in the furnace are distributed as follows:

	Per Cent.
Evaporation of moisture	5
Cooling losses	5
Reduction of the iron ore	24
Separation and fusion of slag	14
Fusion of the pig iron	4
	52
Required for heating blast	14
Balance for use in gas engines	34
	100

As shown in the diagram, 25 per cent. of the gas thus capable of utilization of power is available for external commercial purposes, this amounting to 600 horse-power for every ton of coal, while 9 per cent., or 225 horse-power, is diverted for the operation of the blowing engines and for driving the dynamos to supply the power required for the mechanical operation of the establishment.

Taking together the engines driven by the coke-oven gas and by the blast furnace gas, therefore, there is again available 735 horse-power for every ton of coal used in the furnace.

This arrangement assumes that a modern by-product coke-oven plant is used in connection with the blast furnace, and that there is a market available for the use of the excess power developed. In the case of blast furnaces operated in connection with rolling mills and steel works, there is at hand abundant opportunity for the use of the power thus developed from the waste gases, otherwise another market must be sought. The most probable market available is, in most cases, the illumination of the neighbouring towns and the supply of power to adjoining manufacturing industries. When electric traction for railroad service becomes more general this will afford an abundant outlet for the surplus power of the iron furnaces, while the local electric railways are always available as customers for electrical energy. There is, again, the opportunity for the development of electrochemical works in the vicinity of iron works as consumers of electrical energy, and it is only necessary for the production of surplus power to be exploited according to modern commercial principles to enable it to be utilized to the most advantageous manner.

In order that the best results may be attained, it is desirable that gas-power electric generating sets be designed in large units, in such a manner that entire reliability may be assured, and this is now practically demonstrated, as reference to the November issue of this magazine will show. The large gas engine is now so fully completed that units of 2,000 to 4,000 horse-power may be procured in the open market, while gas-cleaning devices have been perfected to such an extent as to enable furnace gases to be used with freedom and success. Speed-regulating devices, governing by the mixture or amount of combustible, have reached such a degree of perfection as to insure the successful operation of alternators in parallel, just as the driving of delicate spinning machinery is effected. There is, therefore, now no reason why the surplus energy of the blast furnace should be allowed to go to waste, since the methods of utilizing it are fully understood. It requires rather busi-

ness capabilities than engineering skill, involving a perception of the commercial value of the product, together with such effective organization as shall provide markets for the surplus power without excessive cost for disposal and without material loss in distribution. There is no excuse for longer wasting a great part of the thermal energy in the fuel, and the manufacture of the iron should be considered as but one of the objects to be attained in the combustion of the coal, the blast furnace being considered almost as much a gas producer as a metallurgical crucible.

Apart from the desirability of reducing the waste of fuel in present methods of iron manufacture, such systems as that shown in the accompanying diagrams are of interest in connection with the present efforts for the conservation of the natural stores of energy. The duration of the coal supplies of the more densely populated industrial portions of the earth is already within calculable limits. No new coal is being produced, and already engineers and governments are turning their attention to the control and regulation of natural sources of power, especially in relation to hydraulic power and the conservation of rainfall by timber protection.

Under such conditions everything which tends toward a better utilization of existing coal supplies is worthy of attention. The anthracite deposits, much smaller in area than the bituminous measures, appeal first to the engineer who considers the gas-power problem; but by use of the by-product coke-oven many varieties of coking coal are adapted for use in the blast furnace after having been deprived of the volatile portions, undesirable alike in the blast furnace and in the gas engine. Here, then, we see how to reduce the waste of anthracite, while at the same time aiding in the economical production of iron, the power developed from the waste gases of both coke-oven and blast furnace practically releasing that much anthracite from consumption for power production.

The diagrams given herewith are necessarily computed for a single set of conditions, but may readily be modified to suit other data, as may be required. In any case, they afford a graphic and impressive illustration of what may actually be accomplished in the more efficient use of fuel by modern methods.

PRODUCER-GAS POWER PLANT IN THE UNITED STATES

By R. H. Fernald

The excellent work done by the United States Geological Survey in the investigation of American coals, begun at the St. Louis Exposition and continued since, is well known to engineers and manufacturers on both sides of the Atlantic. The results of these tests have been published in various official reports, and from one of the most recent of these we extract the essential features of a review of the present status of producer-gas power plants in the United States, prepared by Mr. Robert Heywood Fernald for the United States Geological Survey.—THE EDITOR.

RECENT developments indicate very positively that two factors will be of great importance in the economical production of power for manufacturing and transportation purposes. These two factors are the replacing, to a marked extent, of the steam boiler and steam engine by producer-gas plants, with their accompanying internal-combustion engines and the centralization of power-production and distribution.

It was only during the latter part of the nineteenth century that the gas engine came into common use, and although many types have been devised within the last twenty or thirty years, it is only within the past five or six years that large engines have been constructed. The development started eight or ten years ago in Germany, Belgium, and England, but marked progress has been limited to the past six years.

For a long time the natural fuel of these internal-combustion engines was city gas, but this was too expensive, except for engines of small capacity. It was seldom found economical to operate units of more than 75 H. P. with this fuel. Cheap gas was essential for the development of the gas engine, but the early attempts to produce cheap gas were somewhat discouraging, and for a time the probability that the gas engine would encroach to any extent on the field of the steam engine seemed very remote. The theoretical possibilities of the internal-combustion engine operating on cheap fuel promised so much, however, that the practical difficulties were rapidly overcome, with the result that the internal-combustion engine is rapidly becoming a serious rival of the steam engine in many of its applications.

The development of large-sized gas engines within the last few years has been exceedingly rapid. It was only seven years ago that a 600 H. P. engine, exhibited at the Paris Exposition, was regarded as a wonder, but to-day four-cycle, twin-tandem, double-acting engines run as high as 6,000 H. P.

The rapid advance of the large gas engine has been made possible by improvements in the production of cheap gas directly from fuel through the aid of the gas producer. An early form of producer introduced in Europe, and now in very general use both abroad and at home, is known as the suction producer, a name suggested by the fact that the engine develops its charge of gas in the producer by means of its own suction stroke. Although many producers of this type are now used, most of them are small, not exceeding 150 H. P. As far as known the first suction producer operated in the United States was installed in 1903, although producers of other types were tried in this country as early as 1896. A serious limitation to the utility of the suction producer has

been the fact that, owing to the manner of generating the gas, no tarry fuels could be used, a restriction that prevented the use of bituminous coals, lignites, peats, and other like fuels. The fuels in most common use for producers of this kind are charcoal, coke, and anthracite coal, although attempts are being made so to construct suction plants that they can be operated on bituminous or tarry coals.

The pressure producer was devised to meet a demand for the concentration of power in large units, to replace a greater number of engines of smaller power. By this producer the gas is generated under slight pressure, due to the introduction of an air and steam blast, and stored in a holder until it is required for the engine. As the gas may thus be stored before passing to the engine, and as it is produced under pressure and its generation does not depend on the suction stroke of the engine, tar and other impurities may be removed from it by devices that permit the use of bituminous coal and lignite. In the progress of invention in this field the pressure producer was closely followed by the down-draft producer, which fixes the tar as a permanent gas and therefore completely uses bituminous coal and lignite.

Pressure and down-draft producers have been in operation for the last few years, but the fuel used in most of them has been anthracite coal. Some plants, however, have used a few well-tried bituminous coals known to be especially free from sulphur, ash, and tarry matter. It remained for the United States Geological Survey, in its testing plant at St. Louis, to attempt the use of any and all bituminous coals, lignites, and peats, without reference to the amount of sulphur or tarry matter they contained. It is gratifying to note that every coal received has been run through the producer and that the results have been more than satisfactory.

In view of the possibility that the gas engine, with its gas producer, may displace the steam engine, the problem here considered has become so important that the Government made special provision for producer-gas tests at its fuel-testing plant installed in connection with the Exposition at St. Louis. These tests have furnished valuable data on the relative consumption of coal per horsepower per hour when used by the steam plant and by the gas plant.

The steam plant with which tests were made consists of two 210 H. P. Heine boilers, furnishing steam to a 250 H. P., simple, noncondensing Corliss engine, which was belted to a Bullock electric generator.

The producer-gas plant is a Taylor pressure gas producer No. 7, of 250 H. P. capacity. Connected with the producer is the usual apparatus for cleansing and storing the gas before it is delivered to the engine—the economizer, scrubber, tar extractor, purifier, and holder.

The gas engine is of the three-cylinder, vertical, Westinghouse type, with cylinders of 19-inch diameter and 22-inch stroke, rated at 235 brake H. P. on producer gas. The engine was belted to a 6-pole 175-kilowatt Westinghouse direct-current generator. The load on the generator was controlled by a water rheostat, especially constructed for the purpose, through which also the energy developed was dissipated.

This plant, installed in 1904, has been used to make 162 tests, including bituminous coals, lignites, and peats from 26 different States. These tests, the detailed results of which have been published by the United States Geological Survey, were all made in a producer of one size and type, the fuel being used in a gas engine restricted to conditions of steady and uniform load, and no attempts being made to operate the plant in such a manner as to develop the special characteristics of each fuel.

Under these circumstances only general conclusions can be drawn, but

these will be found of both technical and commercial interest. For the behaviour of each special fuel the reader must be referred to the official reports, but it may here be stated that the equivalent pounds of coal as fired per horse-power-hour ranged from 4.20 pounds to 0.84 pounds per horse-power, the average being 1.63 pounds per brake-horse-power per hour.

Comparing possibilities of gas power with the performance of modern steam-power plants, the data given by Mr. Stott, superintendent of motive power of the Interborough Rapid Transit Company, New York City, show that in the conversion of 1 pound of coal, containing 12,500 British thermal units, into electricity there is a loss of 89.7 per cent., leaving but 10.3 per cent. utilized, while the average losses in a producer-gas plant are 76 per cent, with a utilization of 24 per cent. In both of these cases the losses include all the elements from the combustion of the coal to the delivery as electrical energy. The above results for steam are in one of the most recent large plants in the United States, and in the ordinary manufacturing plant operated by steam power less than 5 per cent. of the total energy in the fuel consumed is available for useful work at the machine.

The thermal efficiencies of producer-gas plants, as given by different writers, run as high as 33, 36, 38.5 per cent., and for some plants figures as extravagant as "above 40 per cent." are given. Mr. Stott seems ready to accept a thermal efficiency of 24 per cent. for the best producer-gas plants for comparison with 10.3 per cent. efficiency for his steam plant, but a careful study of the problem has led to a more conservative estimate for the producer-gas plant, namely, 21.5 per cent. In general, the ratio of fuel required per brake-horse-power by steam plant and producer-gas plant, under full load, not counting standby losses, is from 1.8 to 3.7 in favor of the gas plant.

In the above comparisons between the steam and producer-gas plants no consideration has been made of stand-by losses. The result for each plant has been derived from experiments made during continuous operation for a given period. Data on stand-by losses for plants operated during a portion of each 24-hour day are not at present obtainable at the fuel-testing plant. Very few results of experiments relating to this point have been published, and opinions regarding the amount of fuel required for holding fires over night or during idle periods in both boiler and producer plants seem to differ widely. It is probable that the most reliable figures available to-day concerning this matter are those presented by Messrs. Dowson and Larter in their recent book entitled "Producer Gas." The results obtained by these gentlemen from a number of engineers and experimenters, including such well-known experts as Mr. Bryan Donkin, indicate that for plants of about 250 horse-power the stand-by losses amount to about 67 pounds of coal per standing hour for the steam plant and to about 4 pounds per standing hour for the producer-gas plant.

In considering the possible increase in efficiency of the boiler tests with a compound engine, as compared with the simple engine used, the fact should not be overlooked that a corresponding increase in the efficiency of the producer-gas tests may be brought about under correspondingly favourable conditions. Not only is the producer passing through a transitional period, but the gas engine must still be regarded in the same light. In the larger sizes the vertical single-acting engine is being replaced by the horizontal double-acting engine. Other changes and improvements are constantly being made which tend to increase the efficiency of the gas engine, as compounding and tripling the expansions have already increased the efficiency of the steam engine.

As has already been stated, the engine used in the tests here reported is of a type that is rapidly becoming obsolete for this size, viz., vertical, three-cylinder, single-acting.

A brief consideration of these points will lead at once to the conclusion that the producer-gas plant and steam plant used in these tests compare very favourably, and that any increase in efficiency in the boiler tests that might result from using a compound engine can be offset by the introduction of a gas engine of more modern type and a producer plant designed to handle the special kinds of fuel used.

It should be noted that many fuels which give poor results under steam boilers have been used with great ease and efficiency in the gas producer, which thus makes it possible to utilize low-grade coals and lignites that have heretofore been regarded as practically useless. Several of the poorest grades of bituminous coals have shown remarkable efficiency in the gas producer, and lignites and peat have been used in it with great readiness, thus opening the way to the introduction of cheap power into large districts that have thus far been commercially unimportant owing to lack of industrial opportunities. Recent experiments with "bone," a refuse product in bituminous coal mining, have given excellent results, showing an efficiency in the product equal to that reached by good steam coal under boilers.

It has not been the aim of the testing plant to determine the lowest possible amounts of coal that could produce a given amount of power or to determine the highest possible efficiency of the particular producer plant installed. By an act of Congress the work of the plant was restricted to the determination of the possibilities of utilizing bituminous coals, lignites and other fuels for the production of power. In spite of the fact that no series of runs has been made on any one coal for determining the best possible results obtainable, it is, nevertheless, gratifying to report that official records show that as small an amount of dry coal as 0.95 pound per hour has been burned in the producer per electrical horse-power developed at the switchboard, or 0.80 pound of dry coal per hour has been burned in the producer per brake-horse-power, on the basis of an efficiency of 85 per cent. for generator and belt.

As regards the present difficulties in the way of more rapid development of gas producers and gas engines as a means of developing power, a number of inquiries addressed to manufacturers of gas engines elicited replies summarized as follows:

1. The gas engine is not yet so reliable as the steam engine.
2. There is a lack of engineers who know how to run producer-gas power plants.
3. The salesmen are inexperienced and are not familiar with the details of the engines and producers they are handling.
4. There have been a large number of unsuccessful and only partially successful installations made during the experimental period of development.
5. There is a lack of proper design and construction of gas engines and producers in the United States.
6. There is a lack of knowledge and confidence on the part of the public.
7. The heating of factory buildings must be provided for by a heating plant separate from the power plant.
8. There is a lack of types of producers which will gasify bituminous coal satisfactorily.
9. Cheap fuels cannot be successfully used in the suction-gas producer.
10. There is a lack of complete knowledge concerning the successful use of the various fuels in different localities in gas systems.
11. The gas-engine, gas-producer

plant has a large excess in cost over that of the steam-power plant.

The inquiries which produced the above answers were made more than a year ago, and a re-examination of the situation to-day shows the extent to which they have been overcome.

1. There have been good grounds for the feeling that the gas engine was less reliable than the steam engine, but to-day many installations tend to change this impression, as an examination of the records will show.

In order to counteract any lack of confidence in the possibilities of the continuous operation of gas producers and gas engines, an endurance test was undertaken at the testing plant at St. Louis, which demonstrated beyond dispute the possibility of operating continuously a producer plant using bituminous coals for power production. The test began March 8 and continued without interruption until April 1, 1905—twenty-four consecutive days.

The average of six analyses of coal used is as follows:

ANALYSIS OF COAL USED IN ENDURANCE TEST

Moisture	14.68
Volatile matter	30.98
Fixed carbon	42.93
Ash	11.41
	100.00
Sulphur	1.33

12,343 British thermal units per pound of dry coal.

During this entire test calorimetric determinations of the heat value of the gas were made every twenty minutes and volumetric analyses were made every two hours. The average heat value of the gas for the entire run was 156.1 British thermal units per cubic foot, and the average composition of the gas was as follows:

AVERAGE COMPOSITION OF GAS IN ENDURANCE TEST

Hydrogen disulphide (H_2S)	0.0
Carbon dioxide (CO_2)	9.2
Oxygen (O_2)	0.0
Ethylene (C_2H_4)	0.4
Carbon monoxide (CO)	20.9
Hydrogen (H_2)	15.6
Methane (CH_4)	1.9
Nitrogen (N_2)	52.0
	100.0

During the progress of the test the usual observations were made at intervals of twenty minutes, and careful notes were kept of all incidents connected with the operation of the plant. Among the items of interest, those relating to the tar extracted during the test are of special significance, as it has often been stated that no plant mechanically separating the tar could run more than five or six days without shutting down. The total tar extracted during this test amounted to 13,455 pounds, or about 143 pounds of tar per ton of coal burned in the producer.

As the plant was laid out for general test purposes, the passages which the gas was obliged to traverse were far more tortuous than those it would have traversed in a plant installed for power purposes only. As a result, the gas, in passing through a pipe about 3 feet in length, was forced to make three right-angle turns and pass through a water-seal valve, thus traversing a distance of about 20 feet. This construction, necessary only for testing purposes, was unfortunate in connection with this experiment, and, owing to the deposit of tar in the water-seal valve, brought the test to a close at the end of twenty-four days. With this combination of piping removed, even more remarkable endurance records should be made than the surprising twenty-four-day test here recorded.

In order to remove the ashes, which must be taken out at regular intervals, it is usually considered necessary to shut down the entire plant. As such a shutdown would be fatal to an endurance test, a special method of taking out the ashes was employed. The ashes were removed about once every forty-eight hours by simply reducing the pressure

under which the producer was operated and running the plant on the suction basis during the hour required for removing the ashes. The men worked with entire ease and comfort during this period.

During the entire twenty-four days the engine showed no signs of heating, clogging with tar, or other trouble. It ran steadily at all times, and at the end of the test was in perfect condition. The same set of igniters was used throughout the run, and gave absolutely no trouble. An inspection of the engine at the close of the test showed that the cylinders, igniters and all working parts were in such excellent condition that the engine was not even cleaned nor its mechanism in any way changed before beginning the next test. An inspection of the producer plant at the close of the test also showed that everything about the plant was in excellent condition, and the regular tests went on as usual after the close of the endurance run.

During this test an average of 225.5 brake-horse-power was maintained. The coal consumed was 1.40 pounds of dry coal per brake-horse-power per hour. Especial attention is called to the fact that during this test, as well as during all other tests conducted at this plant, no attempt was made to remove the sulphur from the gas before it entered the engine. Considerable controversy has arisen in various parts of the country regarding the influence of sulphur on the cylinders of a gas engine, leading to the introduction of this question into some important lawsuits. The engine used at the testing plant since its establishment has received the full charge of sulphur contained in the gas, and shows absolutely no sign of injury from this source, although some of the coals used have contained as much as 8.1 per cent. of sulphur.

2. There is still a lack of competent engineers who know how to run producer-gas power plants, and this difficulty is one which time alone can remedy by extended experience.

3. The inexperience of salesmen has undoubtedly produced much trouble, but this phase of the situation is rapidly improving.

4. The bad impression made by early unsuccessful installations must be conceded, but this has largely been due to the tendency to test plants on the customer, instead of testing them thoroughly before putting them out. This difficulty is being rapidly overcome.

5. Many engines have undoubtedly failed utterly from defective design and inapplicability to the work to which they have been applied. Manufacturers realize this fact thoroughly at present.

6. The lack of confidence on the part of the public has been principally due to the foregoing defects, and will be overcome as they are remedied.

7. Separate heating plants are sometimes necessary, although the heat from the exhaust, or from producer-gas directly, may solve this point.

8. Producers capable of dealing with bituminous coal are now in the market, and the possibilities in this direction have been established beyond doubt.

9. Cheap fuels have not yet been successfully used in the suction producer, and this does form a limitation to its use.

10. The work of the Geological Survey has answered the lack of knowledge formerly existing as to the possibilities of American coals for gas power.

11. The cost of gas-power plants is still in excess of steam plants, but this difference is being equalized. For plants of 4,000 to 5,000 horse-power, the costs are about the same, but for small plants there is an advantage for the steam. The excess cost, however, is soon wiped out by the superior economy of the gas-power plant in operation.

During the summer of 1906 it was my privilege to visit several of the producer-gas power plants of the

country with the idea of ascertaining from their owners and operators their exact uses, efficiency and defects. No selection was made of the plants to be visited. The list included producers made by fourteen manufacturers, and the territory visited extended from Maine to Central Nebraska.

The deductions made from these visits are:

1. The plants as a whole are giving remarkable satisfaction, considering the very brief period of development that has passed since the introduction of this type of power.

2. The most serious difficulty seems to arise from the lack of competent operators to run the plants rather than from defects or troubles inherent in the plants themselves.

3. Inexperienced salesmen are undoubtedly to blame for serious misrepresentations and misunderstandings.

4. The neglect shown by some manufacturers in respect to their plants after they are installed and paid for has not been far-sighted, and the failure of manufacturers to give the purchasers or operators of plants full information regarding their construction and method of operation has certainly been detrimental to the business.

The situation as a whole at the present time seems to be very favourable for the producer-gas plant, not only as to cost of installation, operation and maintenance, but also as to reliability. The successful demonstration at the Government fuel-testing plant that bituminous coals, lignites and peats can be utilized with great economy in these plants should lead to an increase in the use of this form of power within the next few years that may surpass even the most sanguine hopes of the manufacturers.

Current Topics

THE extent and reality of the interest existing in the development of the internal-combustion engine at the present time have been very clearly demonstrated by the manner in which the gas-power section of the American Society of Mechanical Engineers has been accepted by the membership of the society and by the engineering profession in the United States. Although such a section was proposed only at the recent convention of the society, in December last, and although certain formalities had to be arranged before the permanent organization could be effected, the section has shown, at its first public meeting, held on the evening of February 11, a strength and activity which must be taken as an index of the vitality of the subject. There seems to be no doubt that this organization, combining, as it does, the united activities of both technical and industrial engineers, will give added impetus to what is now generally accepted as one of the most important departments in the development of motive-power engineering.

At the first meeting of the section there were presented papers upon the determination of the calorific value of gas fuels, upon the progress which has been made in the development of the gas turbine, upon the applications of combustion motors to the propulsion of tram cars, and upon the importance of definiteness and clearness in specifications and guarantees in agreements relating to the sale of gas producers and engines. This last subject was considered of sufficient importance to justify the appointment of a committee to examine existing forms of guarantees, and to suggest such forms as may remove uncertainties and avoid causes for dispute.

All this is excellent work for a first meeting, and the section will do well if it maintains the pace at which it has started.

Judging from the interest expressed in the proceedings, however, there need be no lack of material, and no occasion to fear that discussions will be languid or perfunctory. On the contrary, the interest of the members and others present was such that they remained long after the formal adjournment, discussing, in animated groups, many of the points of interest in the proceedings of the evening.

It is evident that the period of doubt and uncertainty as to the immediate availability of the internal-combustion motor for practical service is past, and that the machine which converts the heat energy of the fuel directly into mechanical energy without the intervention of a steam boiler is accepted as both re-

liable and advantageous. It is no longer a question as to whether the gas engine shall be used; but rather, where is it most available, and how shall it best be applied to secure the benefits of its great advantages?

An interesting feature which was developed more than once in the course of the discussions was the extent to which all doubt as to the reliability of the gas engine has been removed. The engine, in its various forms, is accepted generally as being as dependable in operation as any form of steam engine, and the former nervous feeling that it might suddenly take on a period of freakish behaviour, rendering it unworthy the consideration of the busy user of motive power, appears to have disappeared almost entirely. In this respect the gas engine has wholly attained its majority, and reached the age of steadiness and reliability which gives it an assured commercial position. This does not mean that no improvement is to be expected. On the contrary, there is much yet to be done toward the perfection and simplification of the combustion motor. But in these respects it stands practically in the same position as the steam engine, and is not in need of improvements as essential to its satisfactory operation, but simply is in line for simplification, reduction in costs of construction and operation, and in increased adaptability for various special departments of work.

The great field for improvement and development undoubtedly lies in the gas producer for the conversion of solid fuel into the gaseous fuel for use in the internal-combustion engine. It is accepted that the producer can enable fuels which are of too low a grade for satisfactory combustion under steam boilers to be used in the generation of power gas. It is not enough, however, to know that such low-grade fuels can be gasefied; the operation must be conducted continuously, uniformly and steadily, in the commercial senses of these terms, before the gas producer can take its place beside the steam boiler as an element in the power plant. Lean fuels mean high percentages of ash, copious production of cinder and much barring and poking of the producer, and these, in turn, mean high labour costs and abundant possibilities for delay. In the largest of all producers—the modern blast furnaces—the cleaning problem has already been met by the use of a flux and by the existence of a temperature zone sufficiently high to fuse the cinder into a liquid slag; and something of this sort may yet come to be considered in producers in which the principal aim is the generation of gas rather than the production of pig-iron.

THE formation of the gas-power section of the American Society of Mechanical Engineers and its progress as a useful auxiliary in the general activity of the society will be observed with interest, both by the membership at large and by other professional organizations. Branch sections of national societies are already in existence, and have proved their value and effectiveness in many ways, especially when the development of an important industry in any particular location brings together many members engaged in parallel lines of work. The gas-power section of the A. S. M. E., however, has been formed under the clause of the constitution of the society authorizing the organization of "professional" sections, the members being drawn together by some common interest in their work, without reference to locality. Such a section is thus as truly national in its composition as is the main society, and it is a matter of note that, in the section just formed, there are members from many States and from widely separated parts of the country.

The advantages of such specialization on the part of the members of a national professional society are obvious. At general conventions of bodies devoted to some broad depart-

ment of professional or scientific work it is almost always the case that the papers and discussions which interest a portion of the members have but little attraction to many others. Men who have come from a distance to attend a gathering lasting but a few days should not be required to spend any considerable portion of that limited time waiting for subjects in which they have a vital interest to come round. Rather should all possible opportunity be provided for every one to give and receive full value for every moment available. This has long been recognized in such bodies as the British Association for the Advancement of Science and in its American counterpart. In like manner, the various international scientific congresses held in connection with great expositions have usually adopted the sensible plan of holding general sessions on the opening and closing days of their gatherings only, the work for the intermediate days being distributed among professional sections in such a manner as to provide interested activity for nearly every one in attendance.

In the United States, the venerable Franklin Institute has for many years included in its work the conduct of a number of professional sections, these having their own organization and control of their own work, subject to the general supervision of the Institute, and it is somewhat in a similar manner that the American Society of Mechanical Engineers is now permitting such an internal segregation of its members. That the result will be wholly advantageous there is every reason to expect, and it is extremely probable that a number of other professional sections will follow the example already set.

This movement will, apparently, solve a problem which has presented itself at a number of recent conventions of the society, the question of handling effectively the increasing numbers in attendance with respect to their varied interests and inclinations. At the recent convention in New York, it was found advisable to hold separate and simultaneous sessions for the discussion of papers relating to foundry practice and those devoted to gas-power matters, and this plan will naturally extend itself at future gatherings, and possibly lead to the organization of other sections.

Such a movement as that which has thus been initiated in the American Society of Mechanical Engineers cannot fail to strengthen the society as a whole and extend its usefulness very widely. Each section will, naturally, become a source of vitality to the main body, both by providing valuable material for discussion and record and by the attraction, as members, of men who, while altogether eligible, have not hitherto been drawn to the organization because of the special nature of their work.

The whole movement forms a part of the modern system of specialization necessary for the successful accomplishment of large undertakings, and there is every reason to believe that it will be attended with abundant success.

TO Brazil will belong in the near future the credit of possessing the most heavily armed man-of-war in the navies of the world. Early in 1907 she placed orders with Sir W. G. Armstrong, Whitworth & Co. for two battleships of even greater size than the *Dreadnought,* and one of these ships has been sublet to Messrs. Vickers' Sons & Maxim. It is understood that these ships will each have a displacement exceeding 20,000 tons. No details have yet been allowed to leak out as to their mechanical equipment beyond the fact that they will have reciprocating engines instead of turbines. This conservative decision has occasioned some surprise in view of the claim which has been put forward by those acquainted with the working of the Parsons turbine that it is far simpler to control than the old

type of propelling machinery. Apart from this fact, a remarkable feature of the Brazilian vessels will be a new type of gun of 13.5 inches. For some months past it has been known that new guns of this size were being constructed, and it was assumed that they had been ordered by the British Government for the vessels of the improved *Dreadnought* type. It now appears, however, that these huge pieces of artillery have been designed for the Brazilian ships. Each of these men-of-war will have four 13.5-inch guns, which are being manufactured at Elswick. So far as is known, no other navy in the world has taken this step towards increasing the size of primary armament in battleships, although it has been rumoured for some time that the matter has been under consideration by the British Admiralty.

THE rapid extension of construction in ferro-concrete of late is somewhat remarkable Engineers have long known that Portland cement would adhere very tenaciously to iron, if clean, and it has long been known that iron ships protected by a lining of cement were thoroughly protected. A recent paper by Mr. de Vesian, the engineer to the proprietor of the Hennebique system, gives a very excellent account of ferro-concrete, detailing the points of chief importance to observe, such as the fineness of grinding of the cement employed, the nature of the sand to be used, washing of the aggregate and sand, the nature of the aggregate, which, contrary to the preconceived notions of many engineers, is better of round pebbles than of these same pebbles broken. The reason for this, apparently, is that a rounded pebble offers every facility for the sand and cement to fill any void, whereas with angular pieces it may often happen that the mortar does not get well into all crevices, and an underneath flat surface may miss making close contact with the motor. Brick, ashes, limestone and slags are not to be employed as aggregates, for they are either porous, tender, corrosive, or insufficiently refractory when heated, a limestone being very apt to flake up if heated by a fire. Silicious materials are the best to use as aggregate, for silica differs in nature from cement, and limestone is too much of the nature of cement to make a good concrete. Mr. de Vesian quotes a special fire test of a ferro-concrete chamber, in which a fire of wood and tar barrels was maintained for two and a half hours. The temperature of the room reached 1,500 deg. F. after some time, but on the adjoining enclosure it only rose 8 deg. F. The fire did not damage the concrete, which was cooled off by water jets, a trying ordeal surely.

THERE has, of late years, been a strenuous set against Hirn's practical theory of the steam engine, the problem of cylinder condensation as established firmly by him after the first discovery of D. K. Clark being negatived. Experienced practical engineers say that Hirn's theory stands good to-day. The new school, which appears to have its headquarters in Manchester, insists that the phenomena we have all hitherto attributed to cylinder condensation must be ascribed to leakage past valves and pistons. Thus, if the steam present in a cylinder be measured in the indicator card at cut off, and when the exhaust opens, it is found to be greater at the time of exhaust. The difference has hitherto been ascribed to cylinder condensation. The new school say it is leakage, but we have yet to see a single valid argument they have put forward to support their contention. If a compound engine be taken and the steam measured at cut off and at exhaust in each cylinder, we fancy the new-school men would find even greater difficulty in upholding their case. They apparently ignore Donkin's experiments, and poor D. K. Clark is packed into the limbo of the

forgotten with Hirn, all on the basis of figures obtained, so far as we have seen, with a little engine totally unfit for experimentation. Nor are the new-school men even original in their claims. The late Mr. McNaught, of Rochdale, the inventor of the axial cut-off piston valve, put forward the same ideas nearly forty years ago, but they never could be substantiated.

LEAD is said to act like steel at ordinary temperatures when reduced to a very low temperature in liquid air. It will serve as a helical spring, for example. These facts, which keep cropping up, of the behaviour of soft, non-elastic metals are very interesting. They show how very important temperature is. Just as iron is soft and inelastic at a high red colour, so lead is dull and soft at ordinary temperatures, for it is well on its way to be melted. Mercury is actually fluid at ordinary temperatures, but can be frozen at about 20 deg. F. into a soft metal. At lower temperatures it may, perhaps, be possible to make springs of mercury. An enormous amount of research lies open to be made on the behaviour of the soft metals, indeed of all metals when cooled to very low temperatures.

A CIRCULAR, recently issued by the Forest Service of the United States Department of Agriculture, is devoted to the subject of the preservation of wooden piles against the ravages of marine boring worms. Apparently the only effective method of resisting the destructive action of these creatures is to sheathe the pile in some other material, the most effective being a casing of iron, a rather expensive plan.

The whole subject is discussed in a special circular, No. 128, issued by the Forest Service; but, apart from any method of protecting wooden piles, the matter suggests the advisability of replacing wood with other material whenever possible. It is practicable, in very many instances, to use piles of reinforced concrete, and thus be assured against the ravages of marine borers, as well as of decay and other forms of deterioration.

The use of water-jet methods of sinking renders such forms of piling especially adapted to marine service, and the difficulty experienced in contending with the enemies of wooden piles makes a strong argument in favour of the use of concrete, reinforced with longitudinal and circumferential rods, for such important constructions.

AMONG the conclusive evidences as to the confidence in the reliability of the internal-combustion motor in its smaller sizes, attention may well be called to the fact that a number of automobiles have started to attempt to cross the American continent, traverse Behring Strait and cross Asia and Europe to Paris.

Naturally the preparations for such an undertaking include the utmost care in the construction and equipment of the vehicles, but in all that has been said as to the requirements to be met, no word has been raised as to the inadequacy or unreliability of the little gasoline engines by which the vehicles are to be propelled.

One of the cars, in fact, is equipped with but a single-cylinder motor, while the others are provided with engines of the four-cylinder type, but these are all of accepted and standard design, and all are assumed to be equal to the unprecedented demands upon them.

It will be a matter of especial interest to observe the record made by these machines, not as to their speed, nor to their power, but as to the extent to which they justify the confidence which has been placed in their reliability; for, however much may be said about speed, economy and efficiency, these requirements, however desirable, are secondary to the one absolute essential in every source of motive power—reliability.

MATTHIAS NACE FORNEY

A BIOGRAPHICAL SKETCH

WITH the death of Matthias Nace Forney, there has passed away a man whose career is impressed both upon railroad engineering and upon the conduct of technical periodical literature.

Mr. Forney was born at Hanover, York County, Pa., on March 28, 1835. His early education was obtained in the local schools, conducted in the old-time fashion, by itinerant instructors; but his natural inclination toward mechanical subjects soon manifested itself. Speaking, in later life, of this part of his schooling, he said:

"Very early in life mechanism and science interested me very much. It gave me great pleasure to decorate the top of our woodshed with miniature wind-mills, to construct water-wheels, which were driven by the stream from a spring near the house, and to make toy cannons out of anything which would hold a charge of powder. My great ambition was to build a small steam engine, but for that my mechanical resources were not adequate, although I made a number of attempts in that direction. Tools and machinery were my delight then, and have been ever since. I then always had a workshop, which was very poorly equipped with carpenter's tools; but it was a source of endless pleasure to me. My first ambition was to be a shipbuilder, then steam engines took hold of my imagination, and finally locomotives got possession of me and have absorbed much of my time and thoughts ever since."

When he reached the age of fourteen he was sent to school in Baltimore, and after three years' instruction he entered as an apprentice in the locomotive works conducted by Mr. Ross Winans. This was probably an excellent place for him to acquire a familiarity with shop work, and especially with the locomotive, a machine which was subsequently to occupy so large a share of his thoughts, since the Winans shop had taken an active part in the development of the locomotive both in America and in Europe, several members of the Winans family having joined with Harrison and Eastwick in the equipment of the St. Petersburg & Moscow Railway, while the Baltimore shops built many engines for the Baltimore & Ohio Railroad, as well as for other roads in the United States. Young Forney spent three years in the machine shop and one year in the drawing room, after which he entered the shops of the Baltimore & Ohio Railroad, and there spent three years in the drawing room.

Seeking some more rapid method of advancement than then appeared possible in the shop, Mr Forney turned his attention to commercial affairs, and from 1858 to 1861 he was engaged in mercantile business; but with the outbreak of the Civil War he left Baltimore and returned to his first occupation, becoming a draughtsman in the shops of the Illinois Central Railroad, in Chicago. This connection was followed, after three years, by engagements with the Hinckley Works, in Boston, and by some other commercial connections. During this period he designed what came to be known as the "Forney" type of locomotive, for which he obtained a patent in 1866, an engine found to be

especially adapted for use later when the elevated railways in New York were put in operation.

His journalistic career began in 1870, when he became associate editor of the *Railroad Gazette,* then published in Chicago. After the Chicago fire the paper was moved to New York, Mr. Forney and Mr. W. H. Dunning becoming joint owners, and it soon occupied a leading position in the railway field, Mr. Forney having had a wide, practical experience in locomotive and railroad shop work, while Mr. Dunning was familiar with the business side of railway transportation and traffic affairs.

During Mr. Forney's active career on the *Railroad Gazette* several important matters came to the front in his especial field of engineering, and his position gave him the opportunity of exerting a strong influence upon them. In England, in 1870, the agitation for narrow-gauge railways began, and, with the vigorous support of eminent engineers and of the technical press, a strong effort was made in favour of the 3-foot gauge, as against the standard gauge of 4 feet 8½ inches. The argument was made that the cost of construction and equipment would be reduced in about the same proportion as the reduction in the gauge, and some progress was made in impressing this opinion upon railway companies. Mr. Forney took a strong position against this view and, although at first almost alone in his efforts, he finally succeeded in checking the idea, and at the present time little or nothing is heard of it. Mr. Forney himself always felt that this opposition to the extension of the narrow-gauge idea was one of the most effective things he ever accomplished, and his name should always be associated with the result.

Believing that the principles of locomotive construction and operation should be made readily accessible to operating engineers, firemen and general readers, he undertook to publish, in the *Railroad Gazette,* a translation of the excellent little German book of George Kosak, in the form of a catechism, this following, in general, the plan so successfully adopted by Bourne in his "Catechism of the Steam Engine," and by similar later works. Finding the German work not wholly adapted to American practice, he abandoned the idea of using a translation, and prepared what was practically a new book, this appearing, after serial publication, as the well-known "Catechism of the Locomotive."

About this time came the development of the idea of the construction of elevated railways as a means of relieving transport congestion in New York City, and the report prepared by Mr. Forney and by Mr. Octave Chanute, in connection with the American Society of Civil Engineers, had much to do with the enactment of the act enabling the elevated railroads to be built. Upon these roads the Forney type of locomotive was installed, and engines of this design were used entirely until the supersession of steam power by electric traction for this service.

From 1872, when Mr. Forney became active in railway associations, he took a vigorous part in the work of the American Railway Master Mechanics' Association and of the Master Car Builders' Association, and it was largely through his efforts that the work of these important bodies became strengthened by a closer association with the railroad companies.

In 1871 a committee of the Master Car Builders' Association was appointed to prepare a "dictionary of terms used in car building." This committee was too large, and it finally narrowed down to three members, Mr. Forney doing the writing and Leander Garey and Calvin Smith acting as consulting members of the committee. After several years of hard work the "dictionary" was completed, and in 1879 it was published by the *Railroad Gazette.*

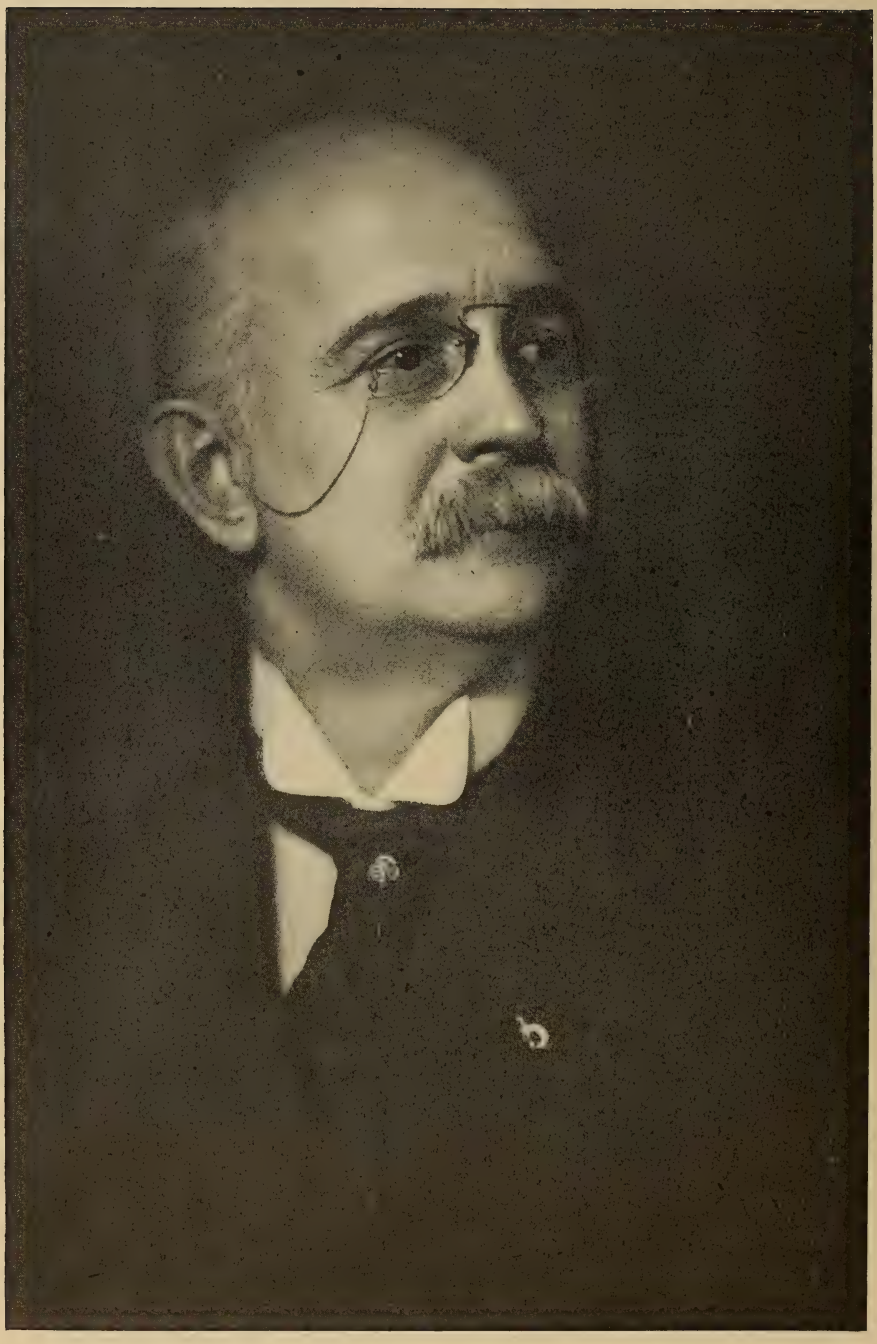
Messrs. Forney and Dunning continued to publish the *Railroad Gazette* until the end of 1883, when Mr. Forney sold his interest to W. H. Boardman, who had been business manager of the paper for several years. For three years following this he was not engaged in any regular business, but this soon became wearisome, and in the latter part of 1886 he bought the *American Railroad Journal* and *Van Nostrand's Engineering Magazine,* and on the 1st of January, 1887, consolidated these two publications under the name of *The Railroad and Engineering Journal.* This he published and edited until the end of 1895, changing the name, however, in 1893 to the *American Engineer and Railroad Journal.* On January 1, 1896, he sold his interest in it to R. M. Van Arsdale, the proprietor of the *National Car and Locomotive Builder,* who then consolidated the two publications. Part of the agreement in making the sale was that Mr. Forney should edit the new paper for one year; in this he was assisted by W. H. Marshall.

Mr. Forney took an active part in the adoption, by railroad companies, of the standard bolts and nuts, now altogether used in all departments of engineering work in the United States, and in every element of his field of engineering he was a consistent advocate of standardization.

Commenting on the career of the man as above outlined, the *American Engineer and Railroad Journal,* to which publication we are indebted for the excellent photograph of Mr. Forney and for many of the preceding details, gives the following summing up of his life:

"Very few men have exerted so great an influence on the upbuilding of our railroads, and none more than Mr. Forney. A large part of his most important and effective work was done a generation ago, and it is impossible to realize fully the far-reaching importance of some of it without understanding the conditions as they then existed. In the 'battle of the gauges,' in the early seventies, Mr. Forney, at that time editor of the *Railroad Gazette,* fought almost alone, at the beginning, against the general adoption of the narrow gauge, and was finally successful in turning the tide. He was very active in the Master Car Builders' and Master Mechanics' Associations; the reorganization of the Master Car Builders' Association, placing it on a representative basis, for which he was largely responsible, has resulted in the standardizing of freight equipment, so that cars may be interchanged over the railroads on the continent. He was active in advocating the adoption of elevated railways in New York City, and for many years the Forney type locomotive was used exclusively on these roads, prior to the adoption of electricity. He was largely instrumental in gathering together and arranging the information in the first editions of the Master Car Builders' Dictionary. It is impossible to estimate the influence of his clear-cut, far-sighted, common-sense views advanced in connection with his journalistic work, when technical journalism was in its infancy; nor can the far-reaching results of such a work as his 'Locomotive Catechism' be computed."

Mr. Forney was one of the charter members of the American Society of Mechanical Engineers and of the New York Railroad Club. He was also a member of the Union League, the Century Association and the Engineers' Club; honourary member of the American Railway Master Mechanics' Association, and a life member of the Master Car Builders' Association. In connection with social and political affairs he took an active interest, belonging to the American Free Trade League, the American Peace Society, of Boston; the Citizens' Union and the Anti-Imperialist League, of New York.



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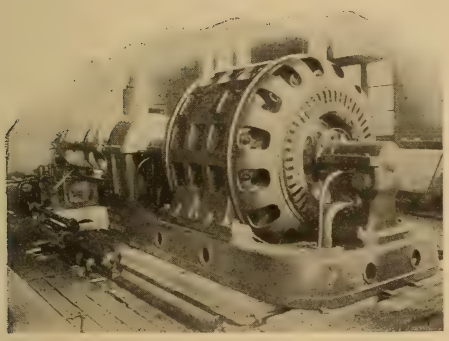
THE OLD AND THE NEW IN POWER-PLANT MACHINERY

By Sterling H. Bunnell



NOVEL forms of apparatus for the generation of power, producing results in some ways superior to the best previously attainable, seem to-day to provide the prospective owner of a power plant with a variety of choice which is almost confusing. A few years ago he would have had no opportunity to do anything but fit up his new plant with horizontal tubular boilers and reciprocating steam engines, with the possibility of a choice between high-speed, direct-connected units and slow-speed Corliss engines, even the latter direct connected in recent years. To-day the power-plant designer has for some years had before him the performances of steam turbines of several types, apparently restricted in use only because of the inability of factories to turn them out fast enough; while at the same time gas engines of large power, deriving their energy from the combustion of gas produced direct from coal in producers forming part of the power plant, have made remarkable records in power produced per pound of fuel. The most conservative man will hesitate, therefore, in making a selection of the type of power-plant apparatus he desires to install, and once having admitted the possibility of the use of something other than the familiar types of reciprocating engines, will find himself bewildered among a multitude of practical questions admitting of various answers.

The reciprocating steam engine has certainly the merit of familiarity from its wide, general use during many years. Its economy is well understood under all conditions of service, whether condensing or non-condensing, or working against back pressure and furnishing its exhaust for heating purposes, and with variable or constant loads. Its cost is also defined on accurate lines, so that the value of a prospective power plant employing engines of this type may be estimated with a high degree of

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accuracy. The familiarity of engineers with engines of this type gives the owner of the plant a good labor market, rendering him nearly independent of any particular chief engineer, and making it possible to employ a force of competent men at moderate wages. The known reliability of such engines is so great that where the cost of power is inconsiderable in comparison with the value of the output, and where the possibility of stoppage or loss of time is greatly to be feared, as in factory service, little consideration has been given to any other type of power-plant apparatus.

From the earliest days of the steam engine inventors have devoted their efforts to devices for doing away with the reciprocating parts of the steam engine. While the steam engine early took its present form, with cylinder, piston, cross-head, connecting-rod and crank, an innumerable number of rotary engines have been devised, each presenting to its inventor alluring prospects of revolutionizing the steam engine business, but proving in the end only a disappointment. It is well known that the inertia effect of reciprocating parts, instead of being disastrous to the wearing qualities of the engine, is actually an advantage to the smooth running of steam engines at high speed. The rotary engine, as that term is usually understood, except in the peculiar scientific toy known as the Tower spherical engine, comprises steam packed surfaces moving in contact on circular lines, with the result that the surface of the joint farthest from the centre, having the highest speed, wears more rapidly than the portion near the axis, with resulting destruction of the tightness of the engine. Further, the expansion of steam has been impossible of attainment with any device of practical value. These defects of the rotary engine are well known, so that it is hardly necessary to more than touch upon the many disadvantages and few advantages of this little-used type. It is only for certain purposes, such as for small motors operated by compressed air or steam for hoisting apparatus or other similar auxiliary mechanism, that the rotary principle has found any application except in the steam turbine.

The records made by steam turbines have attracted the greatest interest and attention from engineers. A few years ago, when the manufacturers of this new type of motor were engaged in their first expensive and gigantic experiments, in which whole power plants were constructed and operated on a commercial basis in order to obtain the necessary data for developing the device, the conservative engineer desiring a new power plant passed over the turbine as an untried novelty. A little later, the progressive engineer was prepared to admit that the steam turbine afforded many advantages; but its use was out of the question because the manufacturers could not construct a sufficient number to supply the limited demand. This condition is rapidly passing, so that to-day the steam turbine is in use in a number of plants, and its limitations are becoming well known, while its advantages may be appreciated without fear of faults becoming exposed after the apparatus is installed and capital invested in the plant. The steam turbine is most successful in large units, probably because the greater profits to be realized in the large sizes have induced the manufacturers to confine their effects to a development of these in advance of the working out of small units. A high degree of vacuum has been considered essential, and as large plants afford the best field for the production of high vacuum by the necessary expensive and complicated outfit of pumps and condensing apparatus, the possibility of the turbine in operation under non-condensing conditions has been little investigated. It is safe to say that no conservative engineer would advocate the installation of non-condensing steam turbines of large size,

or of condensing steam turbines of small size, except under special conditions. While there are a moderate number of small turbines, both condensing and non-condensing, in operation to-day with satisfaction to their owners, there is a much greater number of new reciprocating steam engines doing similar work with equally good economy and quite as much satisfaction. The field of the present steam turbine is, accordingly, confined to large central power-station work, with only a few tentative installations for other purposes; while the reciprocating engine monopolizes the field of power plants whose exhaust steam is to be used for heating purposes, and those plants where condensing apparatus cannot be used.

The possibility of eliminating the steam boiler and of producing power direct from combustion has attracted much attention. The producer gas plants with gas engines for power-plant service are becoming well known, and in every case have proved successful. The novelty of the producer gas plant is at present an objection, as it limits the owner in his labour market. In fact, the owner of such a gas plant may as well make up his mind to training his own engineers or to keeping always in his employ some one of sufficient responsibility to instruct new attendants as changes occur. The extended use of producer gas plants will undoubtedly induce the gradual development of a class of engineers familiar with their management. The cost of the producer gas plant per horse-power is lower than the cost of steam engine and boiler plant, though more than the cost of steam engine alone. The results of the gas engine plant may be realized by considering the usual figure of one pound of coal per horse-power per hour realized in well-run plants of very moderate size. The net fuel cost per horse-power of the producer gas plant is, therefore, far superior to the best results of any but the largest steam plants. At the same time, it must be admitted that the producer gas plant has had limited opportunity for proving its ability to give reliable and steady service, so that the conservative manufacturer may hesitate before installing such a plant in a factory where reliability and steadiness of power are of vital importance, and where even a considerable saving in cost of power cannot compensate for possible delays and shut-downs. There is no available waste heat from gas engines, as the cylinder must be kept reasonably cool, so that the jacket water is not very hot, while the exhaust gases carry no very great proportion of the heat rejected from the cylinder. The producer gas plant is, therefore, a power plant pure and simple, and has no field in competition with steam engines when there is a large requirement for both heat and power.

The relative time of completion of power plants comprising any of the three types of machinery at present offered is apt to be the deciding factor. In most cases earnings are wanted at the earliest possible moment, and a delay of several months for the possible realization of a small saving in power, though perhaps wise in the long run, will not often be permitted. For this reason the average constructor of a power plant gives little thought to the possibility of using improved apparatus, and devotes attention to obtaining the best example of reciprocating steam engine that his knowledge of details of construction permits. The conditions of to-day, however, make it advisable for the designer of a power plant intended to give service over a term of years with the best possible economy to devote his attention to the study of types of apparatus other than the reciprocating steam engine with which he is most familiar, and to remember that the progress of the next few years can do little to improve the steam engine as it is now known, but will certainly do very much toward the improvement of the newer types of power-plant machinery.

FULTON IN ENGLAND

By H. N. Dickinson

THE CLERMONT ON THE HUDSON, 1807

IN the issue of this magazine for September last the work of Robert Fulton in the introduction of navigation by steam on a commercial scale just a century ago, more particularly in relation to the maturing of his plans while in France, was ably dealt with. The period of his stay in England was incidentally touched upon; this period, though not so important—it was only the breaking of the ground, the seed-time being in France and the harvest in America—is so interesting that we may be excused for devoting space to it, especially so now that a bill has been passed by the United States Congress granting a site on the Hudson River for the building of a water gate to New York City as a fitting memorial to Fulton's labours in connection with the Hudson celebration next year.

Fulton's connection with Great Britain may be said to date from his birth, which took place on November 14, 1765, at Little Britain (since renamed in his honour, Fulton) township Lancaster County, Pa., while the Colonies were still loyal to King George III. If we are to believe one author, however, the connection is still closer, for the honour of being his birthplace is assigned to the Mill of Beith, in Ayrshire, N. B.[1] In the absence of authentic documents establishing the identification, this statement may safely be dismissed, merely remarking that the story may have arisen on the supposition that Fulton's forbears were collateral with the Fultons of Beith, and that the former were, therefore, of Scottish and not of Irish nationality, as is usually stated; the surname Fulton, according to the best authorities, is of a local Border origin, and possibly the ruined peel tower of that name in Roxburghshire is the ancestral home of the family.

Fulton was, therefore, in his twenty-second year when he came over to England in 1787 to further himself in his chosen profession of art. He brought with him letters of recommendation to his celebrated compatriot Sir Benjamin West, shortly after (1792) elected president of the Royal Academy. Fulton studied under him, and must have worked assiduously; the position he attained in the world of art may be judged from the fact that he was successful in 1791, and again in 1793, in obtaining admission for portraits from his brush to the exhibitions of the Royal Academy, and further, that in 1791 he had two portraits and two genre pictures hung at the exhibition of the Society of Artists of Great Britain. We may safely assume that this work provided the wherewithal for his maintenance. He lodged during this time at 67 Margaret street, Cavendish square,

[1] Lindsay. "Merchant Shipping," v. IV., p. 590.

FULTON'S SYSTEM FOR CANAL NAVIGATION. FROM AN UNPUBLISHED AUTOGRAPH WATER-COLOR DRAWING BY ROBERT FULTON IN THE POSSESSION OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

The boats are provided with wheels, and drawn over the bridge by a chain traction system operated by a bucket water-motor from the overflow of the canal. The same plan was to be used on inclined planes in place of locks. This drawing bears Fulton's signature and date 1797.

and not in Sir B. West's house, as has been stated.

In London, also, Fulton found himself in a position of which his social gifts enabled him to take advantage, and he made acquaintance with many leading men in the world of art and science.

Fulton now found his way down into Devonshire, possibly executing commissions for pictures or on a sketching tour; but we do not find him again exhibiting, for he had already turned his attention to the subject of inland navigation and of navigation by steam. The latter subject was being given much attention at that time in both hemispheres by a band of scientific men and inventors; in fact, in the United States shortly after the Revolution "a mania began to prevail for impelling boats by steam engines." One of this band of men was Charles, third Earl Stanhope, so well known for his contributions to mechanical and physical science. He had, in 1790, taken out two patents (Nos. 1,732 and 1,771) for a double-ended vessel, which was to be driven by a propeller operating like the foot of an aquatic bird; it was to be in line with the keel and worked by a steam engine. This was really a revival of the proposal made by Genevois, of Berne, in 1759. Having satisfied himself by experiments on a small scale, Stanhope proceeded, in 1792, under the auspices of the Navy Board, to construct an actual vessel, with an engine of 12 horse-power supplied by Messrs. Boulton & Watt, particulars of which appeared in the press.[2]

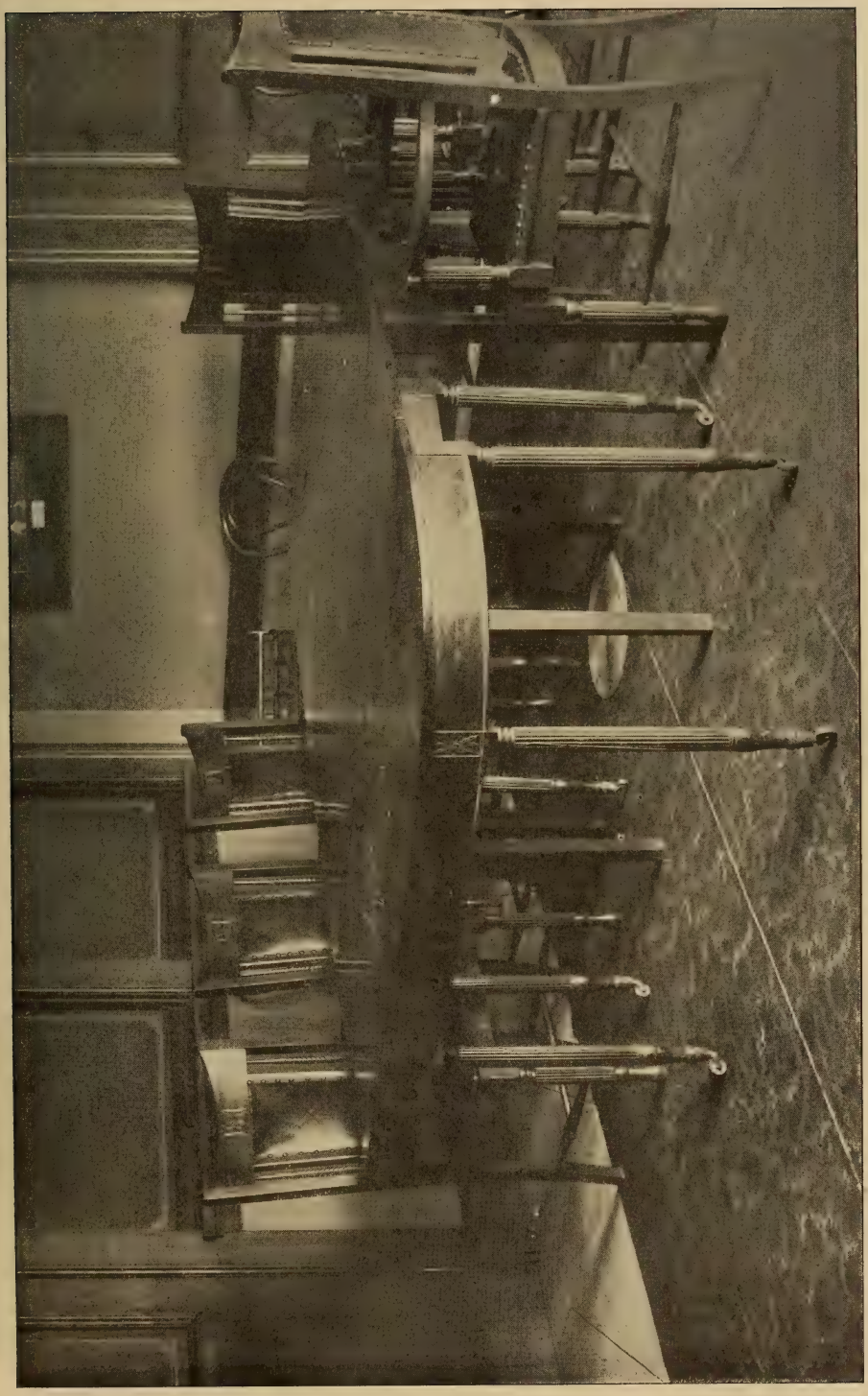
Having seen this notice possibly, and knowing the Earl slightly, Fulton wrote to him on September 30, 1793, from Torbay, in Devonshire, with a proposal to communicate his scheme for moving ships by steam, enclosing also a plan of his inclined planes for canals. This is the first recorded mention of Fulton's connection with either scheme. The letter was duly acknowledged on October 7; the intercourse between the two men lasted till after Fulton returned to the States. Upwards of fifteen letters from Fulton are preserved at the family seat of the Stanhopes, at Chevening, Kent. We are not quite certain whether it was the simple paddle wheel or the chain of paddle floats that Fulton recommended at this time; neither, it may be admitted, was novel, but they had certainly not been exhaustively tried.

The Earl, however, preferred his own duck-foot propeller, and prosecuted his experiments till 1795, in the Greenland Dock, Rotherhithe, but was unable to attain a greater velocity than 3 miles per hour. This dock, it may be remarked, was the scene, from 1793 to 1796, of Col. Mark Beaufoy's well-known "Nautical Experiments" on the resistance of solids to propulsion in water. Fulton kept himself informed of these results, and made use of them subsequently in calculating the horse-power required to propel his vessels.

Fulton remained in Devonshire about twelve months. Possibly he may have been trying to get his system of inclined planes adopted on a canal which was projected between the Bristol and the English Channels, passing from Bude Haven through a mountainous district, and touching the Holsworthy estate of Earl Stanhope. Fulton advocated canals of small size, and to overcome differences in levels, especially where water was scarce, his boats were to be lifted vertically or else provided with wheels, so that they might be drawn up on rails on an inclined plane instead of using locks. For these improvements Fulton took out his one and only English patent (No. 1,988), on May 8, 1794, being then in London, but describing himself as "late of Exeter, gentleman."

In 1794 Fulton also invented a "mill for sawing marble and other stone," which was "at work near Torbay, Devon"; for this he was rewarded by the Society of Arts with their silver medal. He presented a

[2]Gent. Mag., 1792, I.—956.



ROBERT FULTON'S DINING TABLE

Formerly the Council Table of the American Society of Mechanical Engineers, now used as the Board-Room Table of the Trustees of the United Engineering Building, in New York City, in which room this photograph was taken. In the top of the table is a plate bearing the inscription: This table was presented to Mrs. E. (Egleston) House by Robert Fulton, engineer. It passed from her hands to those of George W. Egleston, and from him to his brother, Thomas Egleston, who presented it to the American Society of Mechanical Engineers, January, 1891.

model of the mill to the society; it was placed in their repository, but has long since disappeared.

Fulton's interest in canal navigation next took him, in 1794, to the scene of the earliest efforts in this branch of engineering. He was still studying the subject of steam navigation, for we find him writing to Messrs. Boulton & Watt the following letter[3]:

MANCHESTER, Nov. 4, 1794.

GENTLEMEN:

I shall esteem it a favour to be informed of the Expences of a Steam Engine with a Rotative movement of the purchase of 3 or 4 horses, which is designed to be placed in a Boat. You will Will (*sic*) be so good as to mention what sized boat it would occupy, as I wish to have it in as little space as Possible, and what you consive will be the Expence when finished Compleat in the Boat. Whether you have one ready of the dimentions specified or how soon one might be finished. With Weight of Coals which it will consume in 12 hours, and what Quantity of purchase you allow to Each horse, as I am anxious to supply some Engines of the above dimentions as soon as Possible. Your Emediate Answer will much oblige Your

Most obedient and very humble Servant, ROBT. FULTON.

Bridgewater Arms, Manchester.

Possibly this letter was suggested by the experiment of a certain John Smith that had taken place in June of the preceding year, on the Bridgewater Canal, between Runcorn and Manchester, with a steamboat with paddle wheels worked by an atmospheric beam engine, by which only a speed of 2 miles per hour was obtained.[4] The defects of such an engine were obvious to a man like Fulton, with a grasp of essential principles, although his letter betrays ignorance of all practical details; indeed, it could not be otherwise, as the rotative engine was still Boulton & Watt's monopoly. The policy of the firm at that time was to confine themselves strictly to their established business of stationary-engine building, and not to embark in speculative business. If any reply were sent, it has not been preserved; but what it would have been may easily be surmised.

The letter is dated from an inn, but we know from another source that Fulton was at this time boarding at 8 Brazenose street, Manchester. One of his fellow boarders was Robert Owen,[5] afterwards the celebrated social reformer, at that time managing some cotton mills at Manchester; the two young men quite naturally became friends. Here, as in London, Fulton's personal gifts recommended him; "while * * * forming one of a circle of inquiring friends who very frequently met, he was considered a valuable addition. The late Dr. John Dalton was one of this circle, and Coleridge came occasionally from his college during vacations to join us."

Fulton confided to Owen "that, in prosecuting an invention which had occurred to him, for more expeditiously and cheaply digging or raising earth in forming canals, * * * he had expended all his funds, and he knew not, except by disposing of part of the interest in his patent, how to obtain more, for all his means and credit were exhausted." He said there was a canal to be constructed near Gloucester (this was the Gloucester & Berkeley Canal, Act obtained 1793), "and if I could supply him with funds to go there and see the commissioners appointed to carry it into execution, he might perhaps succeed in obtaining a contract for digging a portion of it."

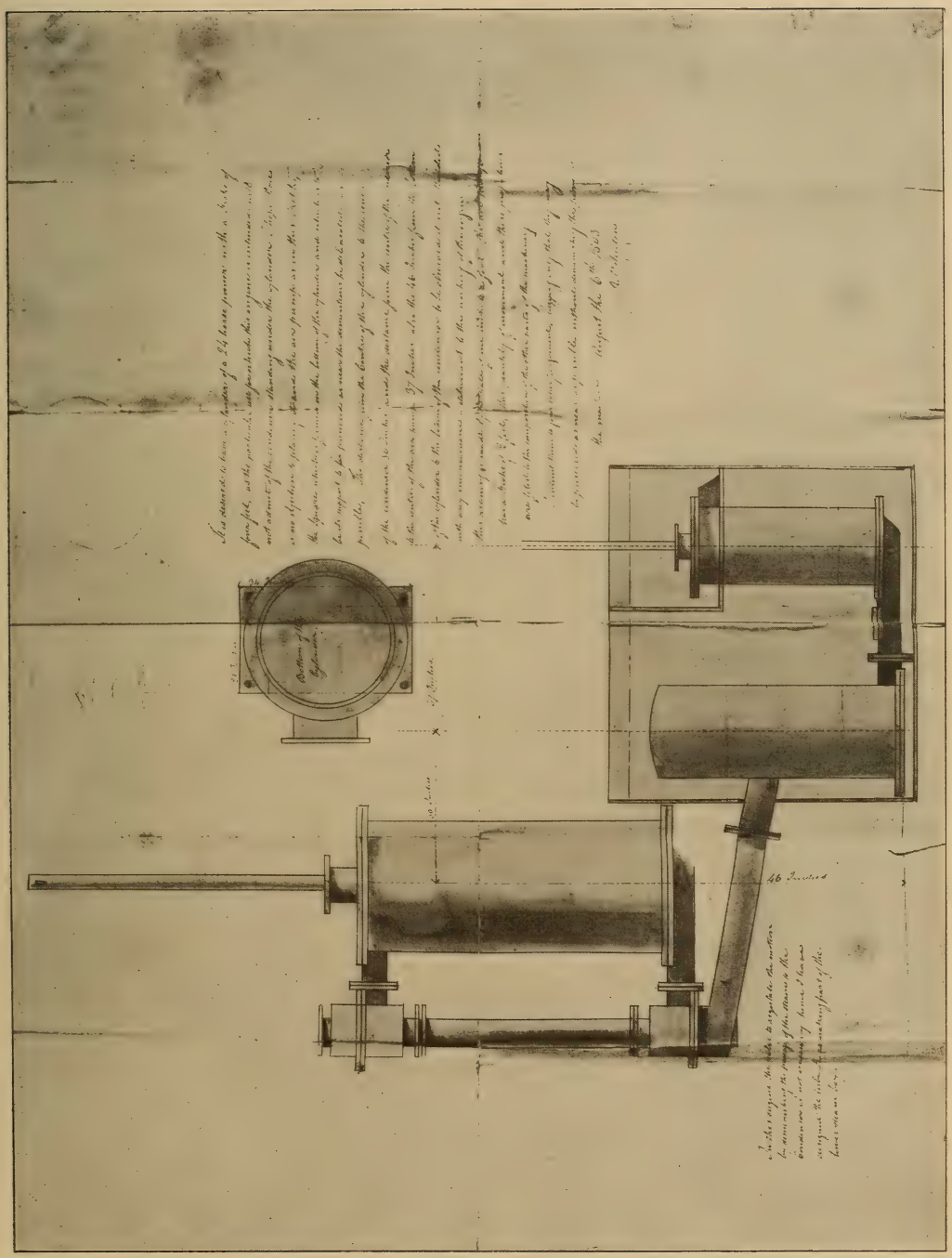
The upshot of it was that, on December 17, 1794, Owen and Fulton entered into an agreement of partnership in the inclined plane and digging machine business, wherein Fulton is described as of the "City of London, Engineer." The document is a lengthy one, but may be summarized succinctly thus:

Owen was to advance immediately

[3]Fulton's correspondence with Soho is now given in its entirety for the first time by kind permission of George Tangye, Esq., of Birmingham, in whose possession the Boulton & Watt manuscripts are.

[4]Nautical Magazine, Vol. I.—1832.

[5]Robert Owen. Autobiography, 1857, p. 64 et seq.



AUTOGRAPH SKETCH AND MEMORANDA ACCOMPANYING FULTON'S LETTER OF AUGUST 6, 1803, TO BOULTON & WATT; NOW FIRST PUBLISHED

The illustration of the machinery of the Clermont on page 610 will show how Fulton intended to complete the engine himself.

£60 towards the expenses of getting the digging machine into operation. Fulton was to "apply his whole time and exertions to the said business" from the date of the agreement. When either of the schemes reached a certain specified success they were to become copartners, equally interested in both inventions, except to the extent of one-sixteenth of the inclined plane patent, which Fulton had apparently already disposed of. Owen was then to advance £400, to be repaid out of the first profits.

Thus supplied with funds, Fulton went to Gloucester at the New Year, 1795. A long letter, with new calculations and diagrams, concluding: "When the rhino is gone I will write to you," followed from Gloucester. This was succeeded by "seven letters in rapid succession, dated from the 14th of January to the 26th of February, 1795, with new calculations, various sketches of new machines and improvements, and asking for more money."

Fulton was now threatened with proceedings by a Mr. McNiven, a canal contractor, with whom he "had had a previous unsettled contract." Owen advised him to come to Manchester and settle the business, which he did. On the 17th of March, 1795, Owen agreed to make his advances to Fulton a debt to be repaid at 5 per cent. interest, as shown by the following:

MANCHESTER, March 17, 1795.

Memorandum.—Mr. Robert Owen, having advanced the sum of £93.8s, in part towards promoting the two projects of running boats independent of locks and removing earth out of canals, it is hereby agreed that the said Robert Owen shall advance to the said Robert Fulton a further sum, not exceeding £80, to enable him, the said Robert Fulton, to make a fair experiment on the earth-removing apparatus; that on finishing such machines, should the said Robert Owen think proper to proceed in the partnership as per contract, he shall be at full liberty so to do. But should a partnership be presented to the said Robert Fulton previous to finishing the said machine, he shall be at liberty to accept of the same on the proposal of the said Robert Owen. And in such case, the said Robert Fulton to pay to the said Robert Owen 5 per cent. per annum for the monies advanced until the said Robert Fulton shall be enabled to refund the principal.

ROBERT FULTON.

Owen did not hear from him till November 2, 1795, when Fulton regretted his inability to pay any part of his debt.

He was occupied during this time with writing his "Treatise on Canal Navigation," 4to, published on March 22, 1796, for the purpose, mainly, of bringing his small canal system before the public. To it he added examples of aqueducts and bridges, not, however, from his actual practice, as has been stated; the whole was illustrated by copperplates from his own hand. Possibly this lessened his pecuniary difficulties for the time being. The book was replied to in 1797 by William Chapman, C.E., and does not seem to have influenced canal practice very much.

The next letter to Owen from Fulton was not written till September 19, 1796, from London; it was in a similar strain to the preceding, but held out hopes that some tanning improvement of his was beginning to be successful, while the canal business was still hopeful. The next letter, written from London, April 28, 1797, contained good news:

"The arrangement I have now made I hope will crown my wishes, having sold one-fourth of my canal prospects for £1,500 to a gentleman of large fortune and considerable enterprise, who is going to reside at New York. Of this £1,500, I shall receive £500 on the 17th of next month, £500 in six months and £500 on my arrival in America, which, I hope, will be about June, '98.

"Now, my friend, this being the state of my money prospects, it becomes necessary that I should deal equal with all my creditors, whose patience in waiting the result of my enterprise I shall long remember with the most heartfelt satisfaction. * * *

"In the appropriation of the first £500 it is stipulated between my partner and me that I should go to

Paris and obtain patents for the small canal system; this, I calculate, will cost me about £200. Of the remaining £300 I will send £60 as your portion and pay you the remainder in six months, which, I hope, will answer your purpose. I shall also be happy to pay any loss you may sustain by paying interest.

"In about three weeks I mean to set out for Paris, and hope to return in time to be with you at Christmas; and about this time next year I expect to set sail for America, where I have the most flattering field of action before me, having already converted the first characters in that country to my small system of canals. My sensations on this business are, consequently, pleasing, and I hope it will please all my friends; to whom remember me kindly." * * *

Owen heard from Fulton from London on May 6, 1797; he repaid the sum of £60 and promised the remainder in five months, but Owen seems to have had no subsequent communication from him.

The exact date at which Fulton arrived in France is not certain, but it was in the autumn of 1797. The business which had taken him thither was soon dispatched, for we find that he obtained a French patent for his canal system on February 14, 1798, for fifteen years. This is a voluminous document of 16 pages and 56 figures in the plates, and was of similar tenour to the English one.

Incidentally, it may be mentioned that Fulton obtained two French patents for panoramas; the first, dated April 26, 1799, for ten years, was subsequently extended to fifteen, on the prayer of the concessionaires, M. and Mme. Thayer; the second was dated April 26, 1801. In conjunction with Nat. Cutting, also, he obtained a patent for fifteen years, dated May 18, 1799, for a rope-making machine.

The causes which led to Fulton's lengthened stay in France have been fully gone into in the issue of this magazine already alluded to, and we must refer our readers to it to study the progress Fulton made with his submarine torpedo and steamboat projects.

Before the final trial with his steamboat, which took place on August 9, 1803, he had written to Boulton, Watt & Co. ordering an engine; the letter, which has been preserved, is as follows:

PARIS, the 6th of August, 1803.

MESSRS. BOULTON & WATT, BIRMINGHAM:

GENTLEMEN—If there is not a law which prohibits the exportation of steam engines to the United States of America, or if you can get a permit to export parts of an engine, will you be so good as to make me a Cylinder of a 24 horse power double effect, the piston making a 4 foot stroke.

Also the piston and piston rod,

The Valves and movements for opening and shutting them

The air pump piston and rod

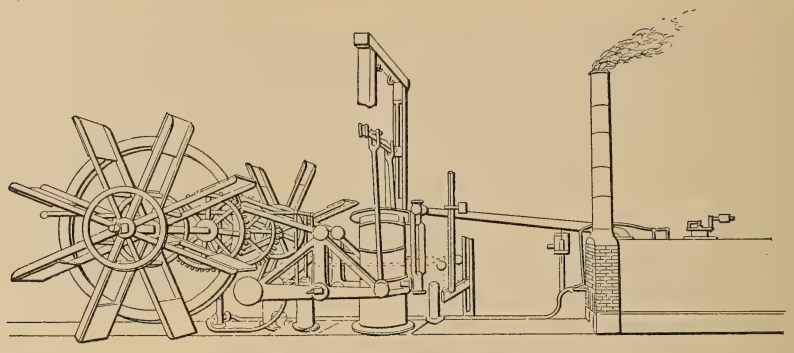
The condenser with its communications to the cylinder and air pump.

The bottom of the cylinder cast in form as in the drawing and the dispositions of the parts as near as possible as they stand in the drawing. The other parts can be made at New York, and as it will save the expense of transport, and they require a particular arrangement which must be done while I am present, I prefer having them done there. Therefore, if it is permitted to export the above parts, you will confer on me a great obligation by favouring me with them, and placing me the next on your list. When finished please to pack them in such a manner as not to receive injury, and send them to the nearest port which I suppose is Liverpool, to be shiped for New York to the address of Brockhurst Livingston Esqre. The Amount of the expenses will be placed to your order in the hands of Mr. George Wm. Erving, American Consul, Nicholas lane, Lombard Street, No. 10, London.

The situation for which this engine is designed and the machinery which is to be combined with it, will not admit of placing the Condensor under the cylinder as usual, but I hope the communicating tube to the condensor, will not render the condensation less perfect, or Injure the working of the engine.

Should you find a difficulty in getting a permit to export the parts above mentioned, I hope to be able to obtain it through our Minister Mr. Monroe. And as there is some difficulty in passing letters to and from Paris and Birmingham, which may lose much time, You will be so good as to furnish me the above parts as soon as possible without waiting to hear further from me.

Please to write me as soon as possible



THE MACHINERY OF THE CLERMONT, 1807

under cover to Mr. Erving as before mentioned, in which I beg you to Answer the following Questions:—

What must be the size of the boiler for such an engine? How much space for the water, and how much for the steam? What is the most improved method of making the Boiler, and economic mode of setting it? How many pounds of coal will such an engine require per hour, and what is the expence at Birmingham?

Can you inform me what is the difference in heating with coals or wood, As in most cases wood must be used in America, And must not the furnace be made different when wood is to be used?

What will be the consequence of condensing with water a little salt? As in the place where the engine is to work the water is brackish?

What will be the Interior and exterior diameter of the cylinder, and its length, and what will be the Velocity of the piston per second? This information will enable me to combine the other parts of the machinery.

When can the engine be finished, and how much will be the expence? Your favouring me with the execution of this order, and answering the above questions, will very much oblige your most Obedient,

ROBERT FULTON.

rue Vaugirard No. 50 à Paris.

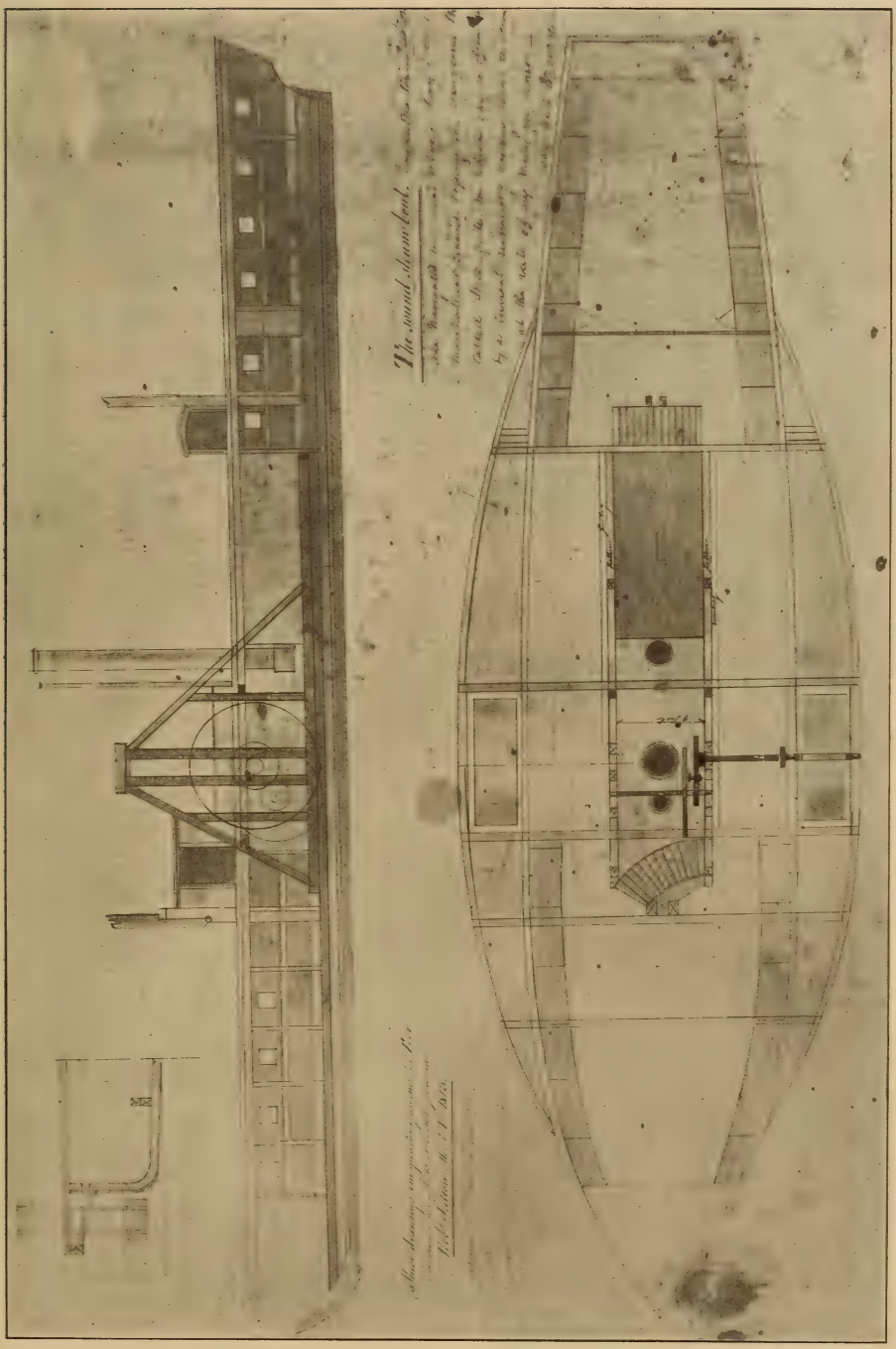
Can the position and arrangement of the Cylinder Condensor and air pump be adhered to, as in the drawing, without Injuring the working of the engine?

This letter was enclosed in a sheet on which was the drawing mentioned; this is reproduced herewith. The manuscript note reiterates the instructions in the letter.

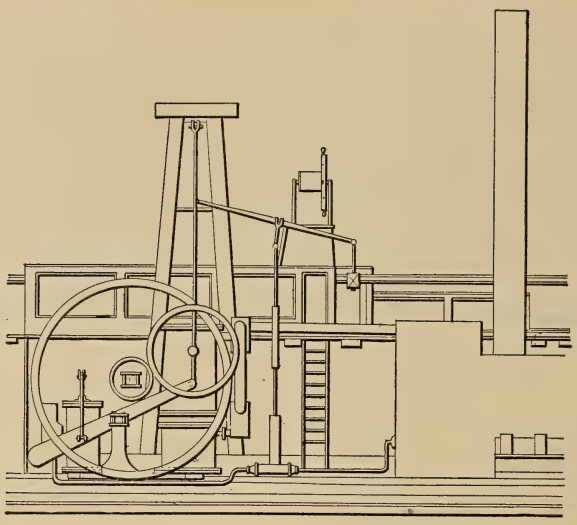
In their reply to him in Paris, dated October 4, 1803, the firm decline the order, owing to their having been unable to obtain the necessary permission to export the articles ordered.

Meanwhile, war had again broken out between Great Britain and France. Information as to Fulton's success in torpedo warfare had been brought prominently before the British Cabinet by Lord Stanhope, and it was deemed advisable to withdraw Fulton from France. Having agreed to that course, the latter went from Paris to Holland, in October, for the purpose of meeting a secret agent of the British government. After remaining there three months, without any result, he returned to Paris; here he met the agent, who induced him to proceed to London, where he arrived in May, 1804. It appears that, from the first, the idea was to bribe Fulton to undertake not to prosecute his method of submarine and torpedo attack, which it was felt menaced Great Britain's supremacy on the seas, the one power in Europe invulnerable to Napoleon. A commission, consisting of Sir Joseph Banks, the Hon. H. Cavendish, Admiral Sir Home Popham, Major W. Congreve and John Rennie, was appointed, who reported adversely to Fulton's submarine boat, without even calling upon him to give evidence!

It would appear that Fulton must have visited Soho in person in the following June or July to renew his application for an engine, for an estimate amounting to £380 was sent to him on July 4, 1804; it comprised



AUTOGRAPH DRAWING BY ROBERT FULTON OF THE FULTON, THE FIRST STEAMBOAT FOR THE NAVIGATION OF LONG ISLAND SOUND, 1813. FROM THE ORIGINAL IN THE POSSESSION OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS



ENGINES OF THE FULTON

a cylinder 24 inches in diameter by 4 feet stroke, with valves, working gear, condenser, injection cock and air pump, delivered at Soho, thus avoiding the difficulty which had prevented the firm estimating the previous year. Fulton requested the air pump to be made of brass; this the firm agreed to, in a letter dated July 25, which contained replies to most of the points raised in Fulton's letter of August 6 of the preceding year, enclosing also a sketch showing the air pump placed in the condenser. Fulton approved of this in a letter[6] dated July 28, 1804, and apparently the work was at once put in hand; for, in reply to Fulton on December 22, the firm wrote to say that the engine was complete and had been erected and taken down again, but would be re-erected for his inspection if desired; however, Fulton waived this point. On January 17, 1805, the firm sent in their account: £400 for the engine and £148 extra for difference in cost between brass and iron for the air pump. The reason given was the familiar one, i. e., "the advanced price of copper"; how engineers' mouths will water nowadays to hear of such prices! The goods left Soho on February 6 by canal, and reached London eight or ten days later.

The last letter of this correspondence is dated February 26, in which the firm returns Mr. Erving's guarantee for the payment of the money.

Considerable stress has been laid upon the visit which Fulton admittedly paid to William Symington to see the *Charlotte Dundas* tried on the Forth and Clyde Canal and upon the valuable nature of the information carried away by Fulton; the dimensions of his engine have even been said to have been borrowed. The date of the visit, as given in affidavits made a quarter of a century later, is stated to have been in 1801 or 1802. The boat was not, however, finished till 1802, and it does not appear that these experiments of Symington were made known publicly, so that the knowledge of them could only have got across the Channel to Fulton through correspondence with his friends. Fulton's movements in 1802, as recorded by his letters and manuscripts, do not admit of sufficient time for him to have taken a journey as far as Scotland, although the Peace of Amiens

[6] Already published in Trans. Inst. Nav. Arch. XL., p. 110.

(March, 1802) would have given the necessary opportunity. The date of the visit could not, therefore, have been before 1804, after Fulton had ordered his engine. The difference between the plans of the two engineers is sufficient also to convince an impartial mind that there was no plagiarism. Symington had a horizontal engine acting directly on a single stern paddle wheel, while Fulton had a vertical bell-crank engine connected to drive two paddle wheels. Whatever information Fulton derived from his visit, it could only have served to confirm him in the belief that he was on the right track.

The work that Fulton did in England in torpedo warfare has been already dealt with.* It ought, perhaps, to be said that he was not actuated by merely sordid considerations in transferring his services from France to Great Britain. He appears to have held the opinion, like so many other enthusiasts, that ultimately his inventions would do away with naval warfare altogether by rendering it impossible. Consequently, when rejected by France, we find that he refused to be stifled by Great Britain. What took place may best be given in his own words, in a letter to Joel Barlow, in September, 1806, on the eve of his final departure from England:

"My arbitration is finished and I have been allowed the £10,000 which I had received, with £5,000 salary, total £15,000, although £1,600, which I have received on settling accounts, will just square all old debts and expenses in London and leave me about £200. My situation now is: my hands are free to burn, sink and destroy whom I please, and I shall now seriously set about giving liberty to the seas by publishing my system of attack. I have, or will have when Mr. Parker sends my two thousand pounds, 500 sterling a year, with a steam engine and pictures worth two thousand pounds. Therefore, I am not in a state to be pitied. I am now busy winding up everything, and will leave London about the 23d inst. for Falmouth, from whence I shall sail in the packet the first week in October, and be with you, I hope, in November, perhaps about the 14th—my birthday—so you must have a roast goose ready. Do not write after receiving this. The packet being well-manned and provided, will be more commodious and safe for an autumn passage, and I think there will be little or no risk; at least, I prefer taking all the risk there is to idling here a winter. But although there is not much risk, yet accidents may happen, and that the produce of my studies and experience may not be lost to my country, I have made out a complete set of drawings and descriptions of my whole system of submarine attack and another set of drawings with description of the steamboat. These, with my will, I shall put in a tin cylinder, sealed, and leave them in the care of General Lyman, not to be opened unless I am lost. Should such an event happen, I have left you the means to publish these works, with engravings, in a handsome manner, and to which you will add your own ideas—showing how the liberty of the seas may be gained by such means and with such liberty, the immense advantages to America and civilization; you will also show the necessity of perfecting and establishing the steamboat and canals on the inclined plane principle; * * * all my pictures, prints and other things I mean to leave here, to be shipped in spring vessels about April next, when the risk will be inconsiderable." * * *

General Lyman succeeded Mr. Erving as the American Consul in London. The pictures referred to were West's "Ophelia" and "King Lear," which Fulton bought in 1805 at the sale of the Royal Academy pictures, for 125 and 205 guineas, respectively, as the nucleus of a Gallery of Fine Arts to be established in Philadelphia.

*See CASSIER'S MAGAZINE, September, 1907.

EFFICIENCY IN DRAWING-ROOM PRACTICE

By H. S. Knowlton

TO increase the speed of production without sacrificing the quality of work done in the modern drafting department is one of the most desirable improvements that can be effected. So much attention has, of late, been paid to securing larger output in the shop that, in many cases, the drafting room organization has not been brought up to date, and the production of drawings and designs along expensive lines follows as a matter of course. Cumbersome methods are the source of many delays in both routine and special work, and they increase the cost of development in new projects far more than is usually appreciated. Many drafting rooms are tied down by worn-out traditions in regard to styles of hand lettering, or the production of superfluous data and elevations on enormous sheets laboriously filled with lines which serve little other purpose than to confuse the busy engineer or contractor who is hunting for important figures only; others are handicapped by poor methods of filing drawings, reports or statistics; by inferior lighting and ventilation, lack of discipline and a paucity of labor-saving devices.

Clear ideas upon the exact cost of making drawings and designs are none too common in such departments, and as a result estimates of the time and expense of preparing sketches or complete working diagrams of different schemes are often wide of the mark. It is important that those in control of drafting-room policy should conduct the work on strictly business principles. Perfunctory records of hours spent upon one task or another are not enough; what is needed is a full appreciation of the time essential for the proper execution of all routine work and a trained sense of the difficulties of handling special creative jobs, with good judgment as to the amount of labour desirable to expend upon tentative schemes.

Organization is a vital point in the success of all large drafting departments handling a variety of work. These are the days of specialists in drafting, as well as in the larger fields of advisory practice. The design of power plant, steel work may be handled by one set of men; another set will take care of the piping layouts, auxiliary and generating equipment locations, and still others, the wiring arrangements. Constant familiarity with the special difficulties attending each branch of the design of the complete plant tends to facilitate the production of the work as a whole. The supervision and checking of such diverse work in a single room is a task demanding a high grade of engineering ability, and upon the character of this supervision largely hinges the efficiency of the department. The position of chief draftsman justifies a salary, in many cases, equal to that received by other heads of important departments; for inferior men lacking in executive ability, wide, technical knowledge, and a special sense of orderly classification are capable of causing far-reaching trouble and expense in the handling of a drafting organization.

It is unnecessary to elaborate the labour-saving devices now available for service in the drafting room. The main point is to avoid needless

labour by substituting inexpensive methods. Thus, tracing from pencil drawings should be cut down to the lowest possible amount. It is better to press the camera into service in making reproductions for subsequent blue prints or photographs. Motor-driven copying presses fill a special niche, as do mechanical pencil sharpeners, the card index and vertical file, adjustable lamp fixtures, electric fans for drying plates and prints, etc. The small-sized drawing—when possible—is the greatest source of drafting-room economy and possible forced output which can be mentioned. Greater use should be made of pasteboard or celluloid templates in designing. Thus, in power-plant work, the various outlined sizes of boilers, turbines, engines, condensers and pumps should be prepared in celluloid or cardboard on the proper scale and be employed in the arrangement of different schemes of equipment. Sometimes models in pasteboard are equally useful. Unless one has tried it, it is scarcely possible to appreciate the saving in time and mental wear and tear which such templates produce. In most power-plant designs a large number of different schemes must be tried and rejected before the final plans are settled. One of the most discouraging experiences which the draftsman has to face is the repeated rejection of his carefully-prepared plans by executive officers, frequently on account of questions of policy of which he has no cognizance. Anything which can be done to lessen the labour of preparing even temporary sketches or studies is just so much clear gain, for it leaves the draftsman freer to consider the work from more than one standpoint. In this connection, the policy of preparing rough, temporary drawings, instead of finished work, is well in line with the best modern practice. The mistake should never be made in a well-organized drafting department of sending out drawings, no matter of what character, without retaining a duplicate in the files. Requests often come in from the field or shop for rush drawings or pencil sketches on a stray sheet of notepaper; the emergency is great, and it is easy to yield to temptation and strike off a sketch for immediate use, without waiting to secure a copy for the department records. The foreman or transit man may promise to return the sketch as soon as the job is finished, but often this is overlooked, and the door is opened toward demoralization of records through incompleteness.

In many companies the practice is growing of filing data of engineering value in the drafting department, where it will be of use for immediate reference, both on a "line" job and as a guide to future designing. It may well pay in large organizations to employ a man with engineering training to handle this class of work according to some approved method of filing. In cases where the task has been approached from the point of view of the user of such data, the results have been admirable. No clerk with merely a general training can sift statistics of an engineering character and classify them with the breadth of view necessary to render them valuable to the designer. Abstracts of the important details of a specification should be filed in the department, together with complete particulars of apparatus purchased on contracts. It is a common experience to find a chief draftsman's loose-leaf book well provided with most of the details of equipment, but wanting in some important particular, as in the recent case of two similar engines of different size, where the fly-wheel weights and dimensions were wanted. The weight of the smaller wheel was tabulated, but the figure was not available for the larger unit, which was the important point of the inquiry. Parallel information can be obtained from the manufacturing companies if sought after, and the absence of complete data is almost always ultimately the cause of suspended production.

Contact with the shop and with field work has been urged for several years as a valuable means of increased efficiency in the drafting room. It is gratifying to note improved conditions in this respect in many engineering establishments. Nothing will sharpen the blunt corners of the academic mind better than the attrition which occurs in a vigorous defense of methods against the criticisms of the field engineer or shop foreman. The scholastic point of view is not readily driven out of the drafting room as long as that organization remains sufficient unto itself. There is not the slightest doubt that if power-house designers could have had the benefit of practical criticisms from operating engineers in many instances which might be called to mind, the resulting installations would have been greatly improved. The number of tentative designs would have been decreased and the problem solved with greater despatch. Cases have often occurred in which the designers of the plant in detail have not been allowed to visit similar plants before taking up their work, or to follow the course of construction in the actual installation which they created on paper, with a view toward increasing the efficiency of the force through the avoidance of weak or expensive spots developing in the field. This inspection work is, of course, largely a function of the advisory engineer, but a certain amount of observation in the field is indispensable to the best production of designs by the man at the drafting board. The draftsmen are the privates of the trained engineering army, but facilities for the examination of the most modern work should be accorded them to a reasonable degree.

A permanent drafting organization, made up of contented men, imbued with a strong *esprit de corps,* is one of the most desirable, and yet seldom attained, features of specialized engineering industry. It is worth while to consider the personal equation in the drafting room. The constant shifting of draftsmen from place to place is a kind of lost motion, which ought to be diminished, both for the welfare of the companies and the reputation of the men themselves. The impression is strong in many quarters that drafting holds few hopes of advancement to the ambitious man, and the result is, in part at least, a shifting of these men from pillar to post, according to the chances of temporary financial betterment, and the fluctuations of business in the employing companies. Constant changes in this department are a disadvantage all around; the expense of breaking men in to new ways, and the cost of locating misfits by their ruinous mistakes in design, are too great to be repeatedly hazarded. The situation is complicated by the extreme youth of many drafting-room employees, for such persons cannot be entrusted, as a rule, with mature responsibilities, and obviously cannot be paid at remunerative rates until they have become experienced.

We must take hold of this problem afresh if we are to secure the permanent and loyal organization, without which the most efficient work—the least costly per unit produced—cannot be had. The work of the individual draftsman must be watched with more selective appreciation. There must be some chance of advancement to the higher technical and commercial positions, some progressive increase of salary to valuable men on the basis of more definite knowledge of their qualities and work. There is need enough for understudies in the modern industrial organization. Co-operation with the individual shop worker is the great cry of the times in the effort to secure suitable foremen and to better working conditions. It is time that the draftsman be given the chances to prove to far-sighted executives, through quickened powers of production, a broadened outlook, and a closer supervision, his fitness to assume advanced responsibilities.

RECENT DEVELOPMENTS IN THE GAS TURBINE

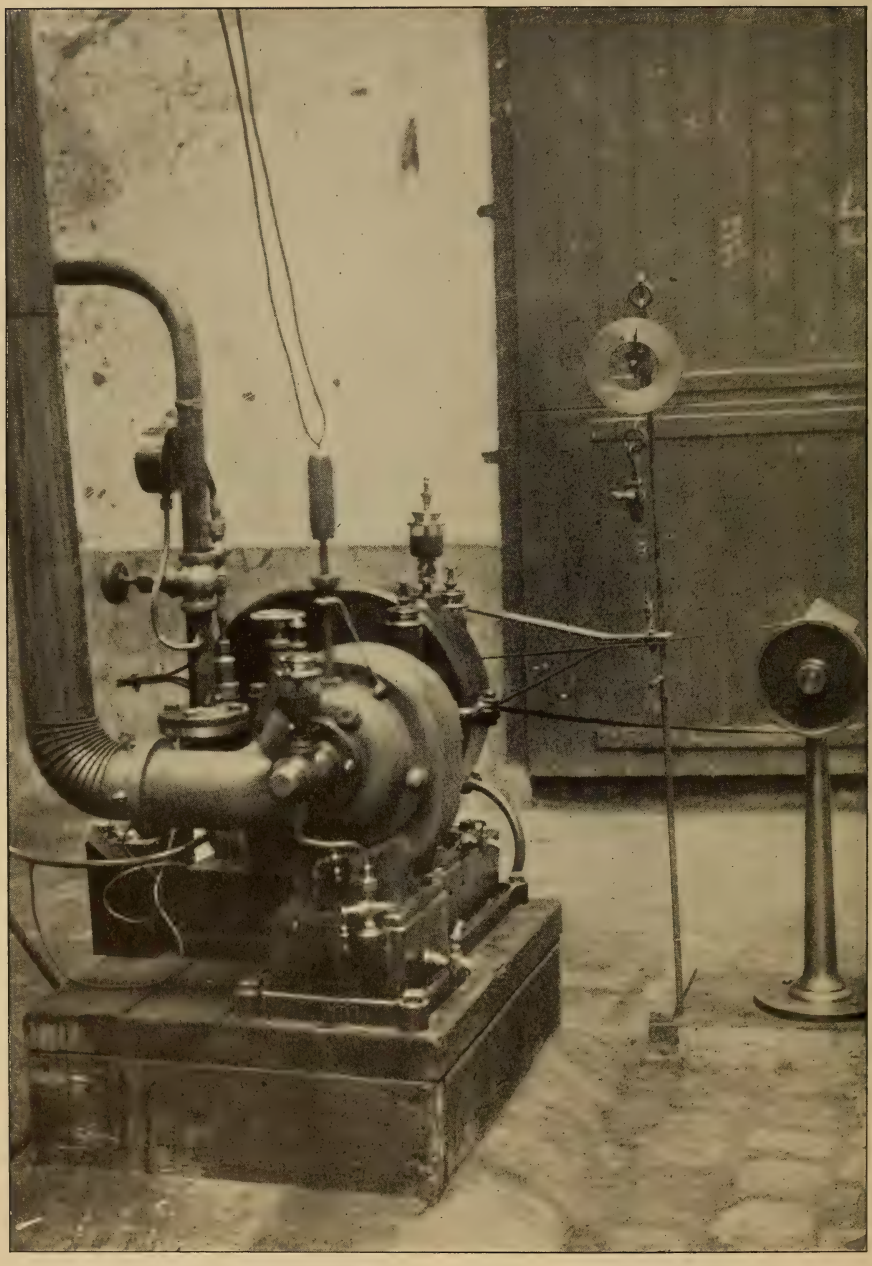
By Alfred Barbezat

IN the issue of this magazine for January, 1907, there appeared an article describing the work which had been done in the development of the gas turbine by M. René Armengaud and his associates, together with illustrations of the 300 horse-power turbine then in the experimental shop of the Société des Turbomoteurs, at Paris, as well as the multicellular turbine air compressor constructed by Messrs. Brown, Boveri & Co., from the designs of Professor Rateau, for use in the same work. The lamented death of M. Armengaud, in the summer of last year, has naturally affected the progress of this important work; but the work has been taken up by M. Alfred Berbezat, who has already been associated with M. Armengaud in these investigations, and the following data concerning the subject will be found of much interest.

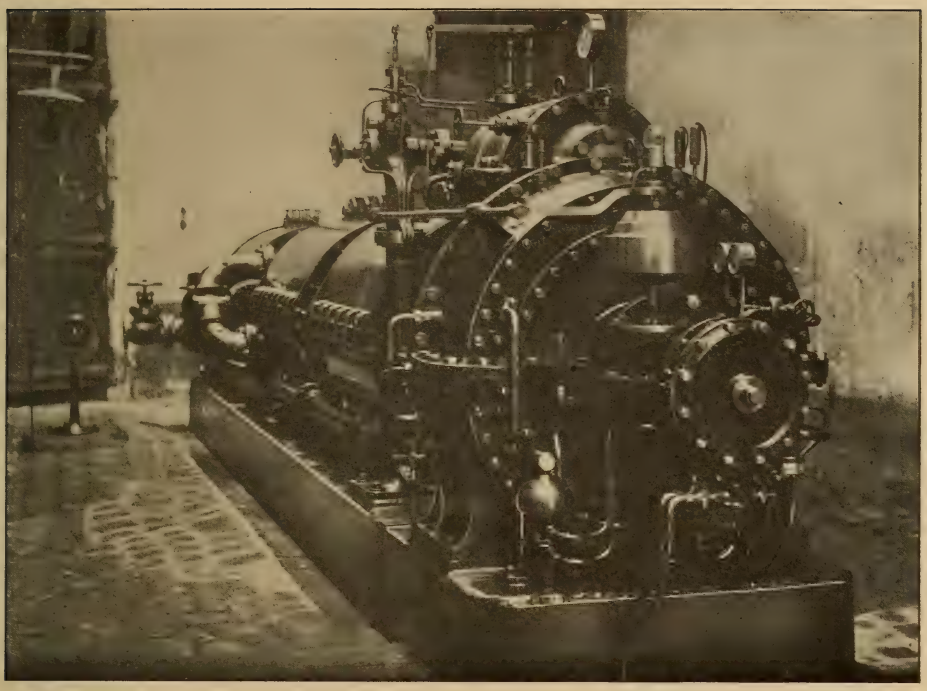
The early experiments were made with a small turbine of the De Laval type, capable of developing about 30 horse-power, and after studying the performances of this machine, when driven by compressed air alone, arrangements were made to test it in connection with a combustion chamber, delivering the products of the combustion of liquid hydrocarbon fuel at constant pressure through a nozzle upon the blades of the turbine. In these experiments the compressed air was furnished from an independent source, the object being to ascertain the action of the combustion in the chamber and the behaviour of the working parts under the conditions involved. This experimental machine is shown in the illustration, and the results obtained with it were sufficiently encouraging to warrant the construction of the larger turbine, shown from various points of view in M. Armengaud's paper referred to above.

The general principle of the machine involves the delivery of air under pressure into a pear-shaped chamber lined with refractory material and provided with an expanding nozzle through which a uniform flow of gases can be delivered upon the blades of the wheel. In the centre of the air nozzle there is arranged an axial tube, with a pulverizer at the inner end, through which the fuel, in the form of gasoline, or similar liquid hydrocarbon, is forced into the chamber. The electric sparking device enables the fuel to be ignited on starting, after which the high temperature of the chamber maintains the combustion indefinitely. The general arrangement of the apparatus is shown in the illustration, this including the nozzle by which the air is fed, under pressure, into the combustion chamber, together with the connection for the gasoline and the electric igniter. The high temperature produced by the combustion greatly increases the volume of the air, and this, together with the gaseous products of the combustion of the fuel, flows at a high velocity through the expanding nozzle upon the blades of the wheel.

In dealing with such high temperatures, the temperature of the combustion being about 1,800 degrees C., the best refractory lining for the combustion chamber has been found to be carborundum, this being a product of the electric furnace, and thus having already sustained even



THE 30 HORSE-POWER EXPERIMENTAL GAS TURBINE OF THE SOCIETE DES TURBOMOTEURS



THE 300 HORSE-POWER GAS TURBINE OF ARMENGAUD & LEMALE CONNECTED TO THE RATEAU MULTICELLULAR TURBINE COMPRESSOR

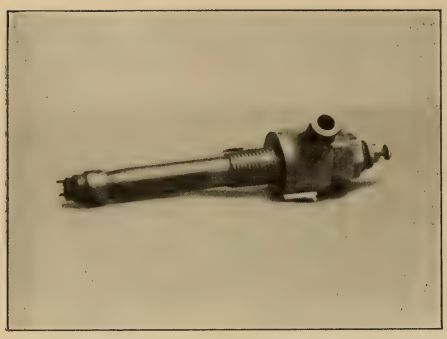
higher temperature than those in the turbine combustion chamber. An elastic backing of asbestos provides for the expansion of the carborundum lining, and the nozzle through which the gases are discharged upon the wheel is also made of carborundum.

In addition to the provision of a refractory lining, it has been found necessary to surround the combustion chamber with a water-jacket in the form of a coil of pipe imbedded in the metal of the chamber walls, much in the same manner as such coils are used in the tuyeres of blast furnaces, and the circulation of the water in the coil aids in keeping the temperature of the combustion-chamber walls within practicable limits.

After the water has circulated in the jacket tube it is delivered, through small holes, into the gases just before they enter the nozzle, and is there converted into steam, this acting both to lower the temperature of the issuing gases to a point where they will not injure the blades of the turbine, and also itself being discharged upon the wheel with the gases and forming a part of the jet, which is thus composed of mingled gas, steam and highly heated air.

In order to obtain the desired result of a machine involving only rotary motion, it is necessary that the compressed air by which the combustion chamber is fed should be produced, not by a reciprocating piston compressor, but by some form of rotary machine, preferably so arranged that it can be coupled directly to the turbine itself. This means that the complete gas turbine must also include a rotary air compressor, and that such a compressor must have a high efficiency in itself, otherwise it will produce such a large proportion of negative work as to detract materially from the efficiency of the combined machine, even though the actual thermal efficiency of the turbine be high.

After a number of experiments



AIR AND FUEL INLET NOZZLE OF THE ARMENGAUD & LEMALE TURBINE

upon single-impeller turbine air compressors, driven at high rotative speeds by De Laval steam turbines, the services of Professor Rateau were enlisted in the work, and a multiple turbine compressor, designed by him especially for this work, was constructed at the works of Brown, Boveri & Co., at Baden, Switzerland. This machine is arranged in three sections and provided with continuous cooling circulation, and, being thoroughly tested, was found to be capable of delivering one cubic meter of air per second at a pressure of 6 to 7 atmospheres, with an efficiency ranging between 60 and 70 per cent.

The illustration shows the arrangement with this compressor coupled directly to the large experimental turbine constructed by M. Armengaud, the turbine and the compressor thus forming practically one machine.

In this arrangement the compressor was found to absorb about one-half the total power developed by the turbine, the machine, when running at about 4,000 revolutions per minute, developing about 300 horse-power over and above the negative work absorbed by the compressor. At the present time experiments are being made upon the thermal efficiency of the machine, which is, as yet, not as high as that of the reciprocating gas engine; but these tests are not yet completed, and the results not available for publication.

During the past few months a practical application of this turbine has been made in connection with the operation of submarine torpedoes.

It is well known that in certain types of such machines the motive power for the brief period which elapses between the discharge and the contact with the target is derived from a store of compressed air, and in some such torpedoes the compressed air acts upon a turbine wheel similar to the steam turbine. This principle has now been extended to the use of the gas turbine, the compressed air from the reservoir passing through a combustion chamber, and the total products of combustion, together with the vapour of water, acting on the turbine, and its capacity thus increased over that operated by compressed air alone.

The turbines made for this purpose develop 120 horse-power at a speed of 1,000 revolutions per minute, the expansion ratio being 8.4. The weight of the turbine alone is 73.16 kilogrammes, or about 1.3 pounds per horse-power. Including the weight of the reservoir of compressed air, together with the petrol and water for a discharge lasting 80 seconds, the total weight of the whole apparatus is about 295 kilogrammes, or a little less than 2.5 kilogrammes, or 5.5 pounds, per horse-power.

Although the gas turbine is, therefore, still in the experimental stage, it has made material advances during the past year, the 300 horse-power combined compressor and turbine being an accomplished fact, and a number of 120 horse-power machines of a special type being actually installed in submarine torpedoes completed for active service. When this rate of progress is compared with the time required to bring the reciprocating gas engine to its present state of perfection, there appears to be reason for encouragement and interest.

THE LONDON 'PRENTICE, HIS CONTEMPORARIES AND SUCCESSORS

By George Frederic Stratton

IT is a far cry to the commencement of the apprentice system in England. Back in the twelfth century we find the first mention of it, but information on the subject is very meagre until the fifteenth and sixteenth centuries, when the apprentice, as a class—especially the London apprentice—had attained a position of much strength and importance; a position, in fact, which seems almost incredible compared with the apparent insignificance of the apprentice class of to-day.

For 250 years the English apprentice was recognized as the future merchant and the future master craftsman, upon whom the English nation relied, almost entirely, for its growing importance among the nations of the earth. In those centuries England was laying the foundations for the commercial and industrial supremacy which, later, brought the little island into the front ranks of civilization, progress and wealth.

The importance with which apprentices were, at that time, regarded was of a vastly different nature to the solicitude with which industrial captains of to-day view them. At the present time they are regarded as the recruits from which the ranks of workmen may be abundantly filled. In the fifteenth and sixteenth centuries they were looked upon as the natural heirs to the business of the nation, whether of handicraft, trading or commerce with other countries.

In those early days business was in small units, and but few merchants and craftsmen took more than two or three apprentices. Often these were his own sons, who, in time, succeeded him in the business; but, if he had no son, one of his apprentices was almost invariably his successor, and very frequently became a member of his family by marriage. An act of Parliament, passed in the reign of Henry VIII., providing legal methods for changing surnames, was obtained at the instance of the merchants of London who desired to perpetuate their names in their business, and who often made such change of names a condition upon the succession of their sometime apprentices.

These apprentices were, in most cases, carefully selected. It appears, in fact, that many of them were younger sons of country squires who, at that time, held a measure of respect for commercial and industrial pursuits which, in the latter part of the eighteenth century, gave place to unqualified contempt. The term of service was fixed by law at seven years, and a fee, or premium, was always paid to the master to reimburse him for the living expenses of the boy, and for his training, until he became of some worth.

The standing of apprentices was, no doubt, greatly enhanced by the many laws made from time to time for their protection and regulation. An act passed in 1410 decreed that all boys offered for apprenticeship must be possessed of property to the valuation of at least one pound per annum—a fairly large amount in those times. This law was, however, repealed about forty years later. From time to time other laws, fixing the amounts of premiums to be paid and enforcing a rigid and proper line of conduct on the part of the masters, were passed. In fact, during this period the greater part of the

laws enacted on the subject seem to have been framed to protect the apprentice from unfair dealing and to ensure his proper training as a craftsman and a citizen.

But much more influential than any acts of Parliament were the rules and regulations imposed by the trades guilds themselves. The formation of these guilds commenced in the twelfth century, each trade, craft or occupation having its separate organization and its hall. No merchant or craftsman could, under the law, do business in London unless he was a member of some guild; and the guilds themselves supplemented this law by a strict rule that no one could become a member without having served a seven-years' apprenticeship under some member.

The guilds also regulated the terms upon which business should be done, and they exercised the strictest surveillance over the integrity and even the morals of the members, with the result that the London merchants and craftsmen enjoyed, for 200 years or more, a reputation for business stability and honesty such as probably never belonged to any great class of business men before or since.

An apprentice became a member of his trade guild at the moment his indentures were signed. He was not, however, admitted to its councils and meetings until he became a master workman.

The awe and veneration with which these guilds were regarded was, naturally, reflected upon even its youngest members, and thus the position and standing of the London apprentice was again strengthened.

The wealth of these guilds soon became very great, and the pomp and dignity of the members rose accordingly. The Aldermen of the City of London were always members of some guild, as also was the Lord Mayor. The Mayor and the merchants were generally deferred to with great respect by both the reigning monarch and the Parliament, for it was to them that the court usually came when short of money. It is not surprising, then, that the boy member of so august and dignified an association, wearing its badge always upon his sleeve, should be viewed with an interest and a respect which we, in these days of the numbered factory boy, can hardly understand.

The impressiveness of the ceremonies with which the boy's indentures were signed and ratified was such as to make a deep and lasting impression upon his mind. It was a solemn affair, which took place in the great guild-hall before many witnesses. The father or guardian presented the boy, who was clad in the regulation 'prentice garb prescribed by law: "Flat, round cap, close-cut hair, narrow, falling bands, coarse side coat, close hose and cloth stockings." The coat bore the badge of the trades guild and the master's own trade sign upon the sleeve. The apprentice was admonished in the following terms: "Ye shall constantly and devoutly, on your knees, every day, serve God morning and evening, pledging Him to avoid evil company, to make speedy return when sent on your master's business, to be fair, gentle and lowly in speech and carriage with all men."

Mutual promises were then exchanged between master and apprentice—the latter on his knees—and the indentures were signed. The ceremony wound up with a banquet in the hall, to which the master usually invited the members of the craft who were his particular friends, which friends also brought their apprentices to wait upon them and get acquainted with their new fellow.

But, dignified as was this occasion and the usual bearing of the masters, the apprentices took many years before adopting this dignity of manner themselves. They were boys and young men, and not easily restrained, especially as they were banded so closely together by guilds. They were strong and redoubtable, with rude, not to say crude, rites of initiation among themselves, plenty of

rivalries between house and house and guild and guild, but with a united, even ferocious, *esprit de corps* against every one else. Fisticuffs and wrestlings were the amenities which passed between them, though always with a love of fair play. But there was no mercy for the coward or the weakly. Such had better betake themselves, at once, to the cloister; otherwise, life was made intolerable by constant jeers, blows, baitings and huntings, often, it must be confessed, absolutely brutal.

They were a solid body in protecting any of their number and in resenting abuse or insult. A cry from the streets: "Flat caps! Clubs! A rescue!" would bring the apprentices rushing from shops and houses. No matter what the occupation was at the moment or the exigency of the master, that cry was instantly responded to. The astonishing readiness and celerity with which they assembled was, in times of discontent with the government, a very serious menace. Frequently the soldiers had to be called out to face these young "Flat Caps," and in such cases blood was frequently spilled and fatalities often ensued.

But the guilds were proud of their boys, and probably the nation was also. So far from repressing their spirits, they were encouraged to engage in rough, out-of-door sports. On every holiday and Sunday afternoons meetings were held in some open space, where running, wrestling and boxing-matches were decided, the prizes frequently being given by the guilds.

King Henry VIII., in his younger days, took much interest in these sports, and frequently attended them. And he never failed to reward the victors, either by some profane words of praise, or, if he had it, a handful of silver.

But there were dark sides to the lives of many of these mediæval apprentices. Strict as were the guilds, there were many masters who were exceedingly harsh, cruel and unjust. In the autobiography of a citizen of London, written in the sixteenth century, a picture of his own apprentice life is given which, in the light of other evidence, may be taken as a fair instance of the lives led by many boys.

He was apprenticed to a scrivener (lawyer) for seven years, his father paying 30 pounds and giving a bond for 100 pounds as a guarantee of the boy's honesty.

This is how he was taught law!

"I was made," he says, "to clean the Shoes, Carry out the Ashes and Dust, sweep the Shop, cleanse the Sink (and a long, nasty one it was), draw the Beer, at washing times to fetch up Coals and Kettles.

"I sometimes went abroad with our Neighbour Apprentices and others, but I must still carry burthens, for, whoever went empty-handed, my mistress would still take care that I had my load to carry, both working-day and Sunday, from our London to our Country house; and rather than I should want a burthen, I was to carry earthen pots and pans, and ox livers and bones for the Dog. This I grumbled at, and when I have been seriously a-drawing writings in the Shop and studying and Contriving how to order by Covenants the best way, a greasy Kitchen-wench would come and disturb me with one of her errands, and tell me I must fetch a farthing's worth of Mustard or a pint of Vinegar or some such mechanical story."

After enduring this servile treatment for three years he complained to his father, the only result being that he was unmercifully caned by his master, although he was then nineteen years of age. It speaks much for the awe and respect in which masters were then held that this young man did not resist this beating, or many others which he got, although, in other parts of his story, we gather that he was no "molly-coddle," but very much the reverse. But the law gave the master authority and permission to flog his

apprentices whenever he deemed it advisable, and the guilds also upheld the law—and it was a very bad apprentice, indeed, who did not respect rules of his guild.

There was graft in those days, too, and some of the London masters did not hesitate to exercise it when they had the opportunity. Another writer of that period says:

"And let me tell you that I have observed and known that some Citizens have much increased their Estates by taking many Apprentices and getting 50 or even 100 Pounds with each one, whereupon they become so severe and rigid, and the boy hath been so Hardly used, that he hath run away in a short time, and, rather than return again, lose all his Money."

This ingenious method of obtaining premiums and then evading the care and training of the boys became too common, and an act of Parliament was passed, limiting the number of apprentices taken by any one master.

In the middle of the eighteenth century the glory and prestige of the London 'prentice began to wane. The conditions of business were changing. Masters were using more capital and employing more hands, with the result that they were not so close to their men as formerly. Towards the close of the century water-wheels were introduced and factory systems commenced—in a very small way, it is true, but the distance between master and man broadened rapidly. The old interest and affection which existed between them when all lived under the same roof and ate at the same table disappeared. Foreign merchants and artisans were now permitted, by law, to do business in London, in spite of the strongest efforts of the guilds to prevent them. The workmen gradually withdrew from the guilds, which soon became, as they are now, composed solely of the employers. The old loyalty and solidarity of the apprentices became greatly weakened, especially since many of the apprentices were taken on by the foreigners. The country gentry, also, had become more settled and exclusive, no longer looking upon trade as a befitting career for their sons. Then, again, the city and town authorities had devised a method of providing for the children of paupers, and even of convicted criminals, by apprenticing them to those who would take them—chiefly the foreign tradesmen. This, of course, discredited the whole system of apprenticeship.

With the advent of steam power, in the early part of the nineteenth century, came the development of the factories, and, for a long time, a sadly unsettled condition of labour. Workmen formed unions to protect themselves against what they considered the tyranny and greed of the masters, and the apprentice was in a sorry plight indeed! No longer in close touch with his master or an inmate of his house, he was turned out into the factory, to become the butt of the workmen, and, in very many cases, the object upon which they vented their spite and disapproval of his presence. For they had already determined that there were too many workmen, and they bitterly opposed the apprenticing of any more boys.

There were still, for a time, many trades carried on as handicrafts, and to these, of course, the boys could go and become good and skillful workmen; but in the factories they learned nothing except to dodge tools thrown at them and to feebly answer back with something of the same profanity with which they were constantly assailed. As the small handicrafts became, in their turn, concentrated into factories, the opportunities for the boys became lessened. When tolerated in the factories, they were put on some special work, and had no opportunity to become all-round workmen. The old method of training and making good craftsmen had disappeared, and it was not until very recently that any system has been devised to take its place.

THE APPRENTICE IN THE COLONIES

The apprentice was never such an important factor in the American Colonies as he was in England. But the spirit of English customs was for long the spirit of the Colonies, and, in the earlier days, boys and girls were eagerly sought as apprentices for both workshop and house. In 1619 one hundred boys and girls—waifs of London—were shipped over to Virginia and apprenticed to whomsoever would pay their passage money. In Stuyvesant's time several invoices of Dutch children, taken from almshouses, were sent to New York, and practically sold to the highest bidders, being bound until they should become of age. An advertisement in an early number of the South Carolina *Gazette* announced:

"Just imported, and to be sold! Irish servants—Men and Women of good trades. Also several boys and girls for apprentices. Prices from Five to Six Pounds!"

For a long period numbers of boys and girls were shipped from England, the town authorities there eagerly seizing the opportunity of ridding themselves of parish charges. And so great was the demand for these young apprentices that many ship captains and super-cargoes did not hesitate to kidnap children from the sailing ports when on the eve of a voyage to America, pocketing the proceeds themselves. Very stringent laws were, consequently, passed to prevent this inhumanity.

This was the only source from which the early colonists could secure young assistants, either for trade or domestic service, none of the sons of the settlers themselves being available for any work excepting with their own parents. The apprentices of those days were, therefore, for the most part, very inefficient and troublesome, consisting almost entirely of the offspring of dissolute, shiftless and often criminal parents. With the blood and the characteristics of the parents strongly marked, those apprentices must have been very serious problems for the master, as, of course, they were always taken into intimate relations with his family.

Then, again, the great moral influence of the guild, both upon master and apprentice, was lacking, there being no such institution.

Among the earliest laws passed by the colonists are found some relating to apprentices. The record of the Massachusetts Bay Colony for 1634 contains an entry that "if any boy that hath been whipped for running from his master be taken in any other plantation, not having a note from his master to testify his business there, it shall be lawful for the constable of the said plantation to whip him and send him home."

It further provides that, if they fled from a cruel master, they were to be "protected and sustained till due order should be taken for their relief." In 1672 the General Court, in its revised laws, provided that "Rude, stubborn and unruly children might be withdrawn from incompetent parents and apprenticed for their minority."

In all of these cases papers were regularly drawn up and signed by the proposed master and the guardian of the child, and, if an old indenture, dated 1710, can be taken as the usual form, the child had much more to think about than the master. Over 600 words are used in defining the duties and responsibilities of the apprentice, but those of the master are comprised in the following: "And the said master, during the said Term, shall find and provide sufficient wholesome and compleat meat and drink, washing, lodging and apparrell, fit for such a Servant."

It was undoubtedly understood that the master was to have the same privileges of discipline and correction as were granted in England. In the diary of the Reverend Peter Thatcher, of Milton, Mass., is this entry:

"Came home and found my servant had liked to have knocked my Theodorah on the head by letting her fall. Whereupon I took a good walnut stick and beat her to purpose, till she promised to do so no more."

Again, in the Middlesex records of 1655 a case is recorded:

"An apprentice complained that his master made him work on Sunday, and further misused him by fastening a Locke with a chain to it and tying and fettering him to the Shoppe, and that said Master, his wife and mother, did most cruelly and inhumanly beat his said apprentice, and also whipt him till he was very Bloody and his fleshe raw over a good part of his body, and then salted him and held him naked to the fire, being so salted, to add to his Pain."

In the latter part of the eighteenth century reliable merchants and craftsmen of the larger cities found no difficulty in obtaining good apprentices—the sons of colonists who were desirous of engaging in city pursuits—and for a long period the character and standing of apprentices in New York, Philadelphia and Boston were equal to the best days of the London 'prentices. But the conditions which were reached in the early part of the nineteenth century in England also prevailed here. Factories took the place of workshops, merchants separated their dwellings from their warehouses and from their clerks and apprentices. The rift in the rock of personal intimacy between employer and employed widened and deepened, and the old-time apprentice disappeared.

For nearly half a century the boy of the two greatest industrial nations on the earth was ignored. He was taken into commercial and manufacturing business only on account of his ability to do work which would save the hire of a man. His training for finer work received no systematic attention. He had to fight his own way upward, and, because a small percentage succeeded in becoming good workmen and rose even higher, the pernicious, disastrous and utterly erroneous opinion took root, that the best training for a boy was, in effect, to toss him into the water and let him sink or swim, according as his own undeveloped faculties and judgment and immature mentality and experience availed him.

But the sun of a better day is rising. That "the boy is father of the man" is more clearly understood at this period than at any time in the world's history. There is still a large proportion of men—parents, at that—who adhere to the "sink or swim" theory; who blatantly assert that the self-made man is the prop of the nation. But the greatest merchants, the greatest manufacturers and the greatest railroad captains, many of whom are themselves "self-made," are the men who, to-day, are the most insistent and the most helpful in devising plans and opportunities for the training of boys to become their successors.

"A boy cannot make himself a good mechanic—he must have training and opportunity. After that he may rise to anything," says Andrew Carnegie.

"There is not a self-made man in the world," says President Tuttle, of the Boston & Maine Railroad. "The so-called self-made man is the one who has seized opportunities given him by circumstances and by other men."

"By other men!" That is the keynote. And those other men are with us to-day. They are endowing great technical schools and libraries. They are using votes and influence for manual training in public schools. They are devising systems for apprentice-training in the factories of the country. The issue is a live one, and, by millionaires and small manufacturers, by heads of great universities and principals of town schools, it is being met nobly and understandingly.

EPICYCLIC GEARING FOR AUTOMOBILES

By T. A. Borthwick

AMONG the mechanical problems which have been encountered in the design of automobile vehicles that of devising a satisfactory and convenient speed change system has attracted the attention of the engineer. Various methods of effecting the necessary changes in speed without altering the speed of the engine have been introduced, these including the engagement and disengagement of gear trains by sliding the combinations longitudinally on the shafts, while other methods involve the use of epicyclic gear trains, this latter plan being especially adopted in cars of American design. To the engineer, the epicyclic train seems most desirable, mechanically and constructively, forming a much more finished piece of work than the sliding-gear system, and hence some examination into the varieties of such mechanism as employed in modern motor cars will be found of interest.

The epicyclic train is adaptable to a number of purposes, especially in connection with high-speed power generators, and admits of such varied and interesting results being obtained by slight alterations in the train of wheels that a short review of the various classes and the adaptability of each should be neither inopportune nor without interest. Before proceeding to deal with the various trains, one or two general notes on the determination of formulæ for the reductions must be made. There is

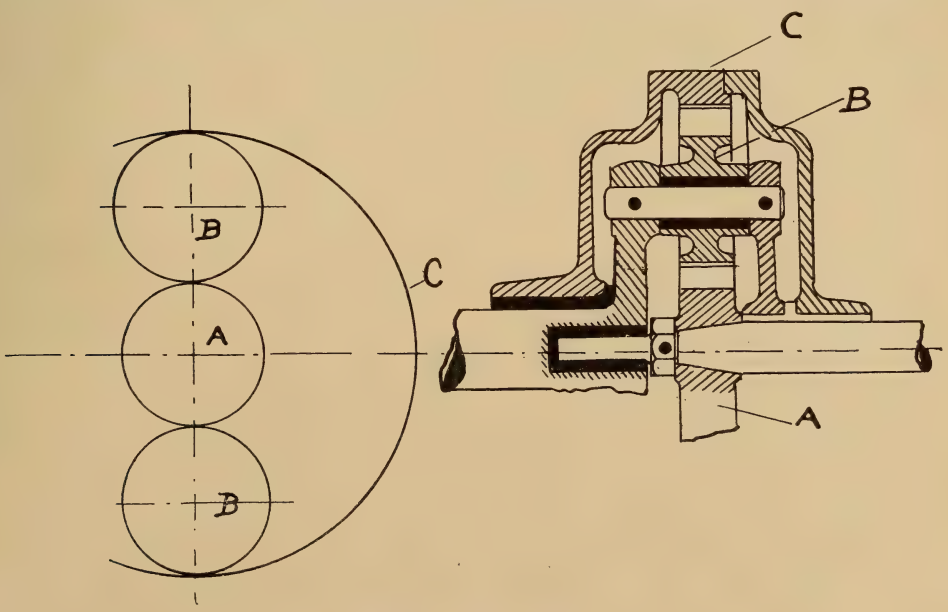


FIG. 1.—SIMPLE SUN-AND PLANET TRAIN.

no doubt that designers have frequently steered clear of epicyclic gearing, owing to their not being clear as to the reduction obtained, and the determination of the more elaborate formulæ for compound trains may appear to be a somewhat complicated task; but the following process may be adopted in almost all cases and reductions obtained in quite a straightforward manner: Almost all trains have (a) a sun, or central wheel, (b) one or more planet or satellite wheels rotating round the sun, and (c) a fulcrum wheel. In such trains the investigation of the reduction should always start with an imaginary rotation of the planet round the sun and consideration of the rotation of the various parts made from this base; the reason of this procedure is that the positively forced revolution appears as a round unit, and is thus easily dealt with.

Starting now with the simplest possible form of epicyclic train, as shown in Fig. 1, we have a sun wheel A meshing with at least two planet wheels B (so that a balanced gear is assured), and these planets, in turn, gear with an internally-toothed fulcrum wheel C. Assuming that a = number of teeth in A, b = number of teeth in B, c = number of teeth in C, and giving an imaginary rotation of B round A, we find that

B performs $\frac{c}{b}$ revolutions about its axis, while A performs: $\frac{b}{a} \times \frac{c}{b}$ revolutions + 1 revolution, since it will be seen that, while we rotated the planet, we also gave the sun a forced revolution, so that the reduction is equal to $\frac{b\,c}{a\,b} + 1$ to 1; or $= \frac{c + a}{a}$ to 1.

This simple form is adaptable to a number of purposes, and, among other purposes, has been extensively used in belt-driven motor cars, steam lurries, reducing the speed of electric motors in a limited space, etc. On reference to the formula, it will be seen that the theoretical limit for reduction of this type is 2 to 1, since this implies sun and fulcrum wheels of equal size; there are, however, mechanical difficulties to going much nearer than 5 to 1. A bevel form of otherwise identically the same gear presents somewhat larger possibilities, and comes more into the range of automobile work; this has been adopted in the Johnston-Buddicum change-speed gear, while for a general commercial purpose we would mention the extremely neat arrangement for gearing up to work the fan on a portable forge, as illustrated in Fig. 2. There is no serious objection to the use of bevel gears, since with up-to-date machinery the teeth can be cut quite as accurately as spur teeth, and should the numbers for manufacture warrant the use of jigs, the difference in cost between a spur and bevel should be inappreciable.

The second type of epicyclic train in common use is shown in Fig. 3, and its formula is derived in a manner similar to the last, as follows:

Revolutions of C during 1 revolution of the planets round the sun equals $\frac{d}{c}$; and the revolutions of B, which is also rigidly fixed to C, also $= \frac{d}{c}$; therefore, revolutions of A $= \frac{b}{a} \times \frac{d}{c} + 1$; that is, the speed reduction will be: $\frac{b\,d + a\,c}{a\,c}$ to 1.

On investigating this formula, it will be found that slightly larger limits of reduction are obtained by it then with the first pattern in spur form; thus, taking A = 30, B = 15, C = 40 and D = 85, we have a

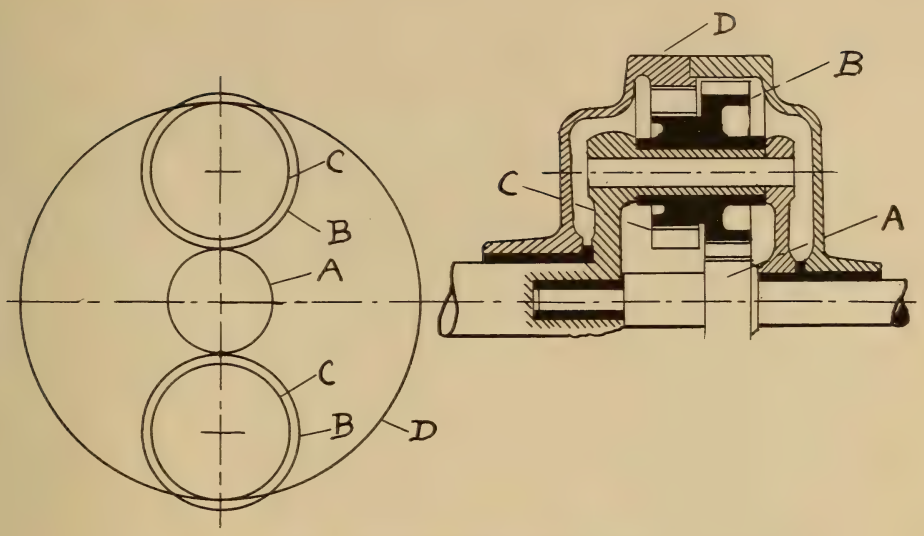


FIG 3 —COMPOUND GUN-AND PLANET TRAIN.

train giving a reduction of 2.06 to 1—a ratio impossible with No. 1 type; and it also offers an additional advantage to counterbalance the addition of an extra wheel in each planet, in that a larger reduction can be obtained in the same over-all diameter. Thus, in No. 1 type, with A = 20, B = 40, C = 100, we have a reduction of 6 to 1; but in No. 2 type, using a train to go in the same diameter, e. g., A = 20, B = 40, C = 20 and D = 80, we have a reduction of 9 to 1, or 50 per cent. greater. The type can readily be arranged in a simple and

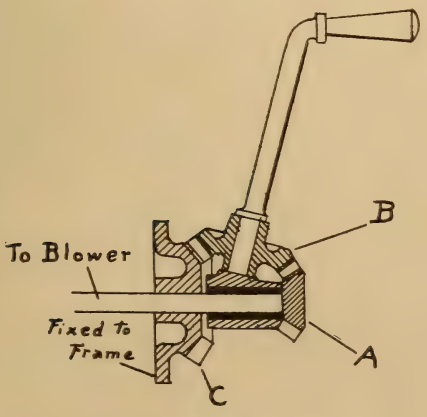


FIG. 2.—EPICYCLIC GEARING FOR FORGE BLOWER

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proportionate design, and is sometimes used on automobile work to obtain the first or second speed.

The third train offers a considerably larger range of reduction than either of the two forms already

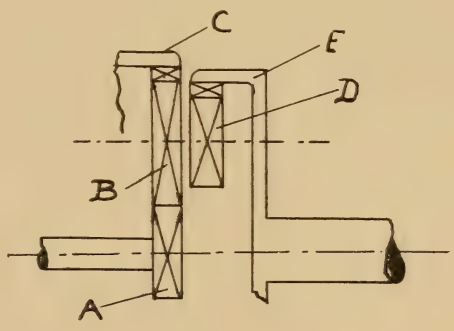


FIG. 4.—HUMPAGE SPEED-REDUCTION GEAR.

dealt with. The arrangement, a patent for which has been granted to Mr. Humpage, is illustrated in a spur form in Fig. 4 and in a bevel form in Fig. 5, and eminently satisfactory results have been obtained from it in practice. The formula for the reduction takes a somewhat more elaborate form than the others, but it is obtained in precisely the same way as those already obtained, e. g., during

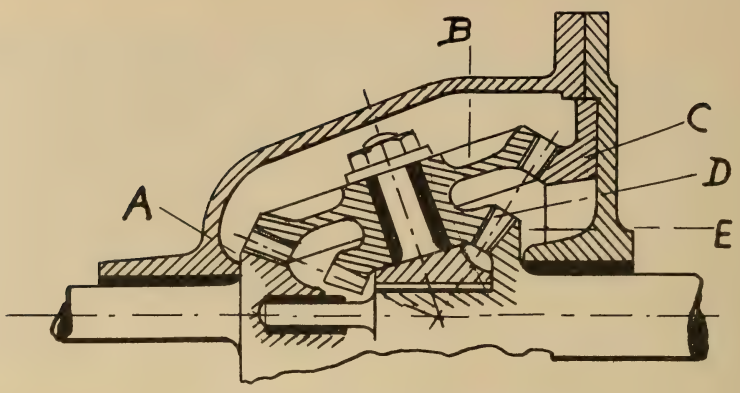


FIG. 5.—HUMPAGE SYSTEM WITH BEVEL GEARS.

1 revolution of the planet around the sun B performs $\frac{c}{b}$ revolutions, and, therefore, A performs $\frac{c}{b} \times \frac{b}{a} + 1$ revolutions, which equals $\frac{c+a}{a}$ revolutions; meanwhile, since B and D are fixed rigidly together, D also performs $\frac{c}{b}$ revolutions, and E performs $\frac{c}{b} \times \frac{d}{e}$ revolutions in a negative direction and one revolution in a positive direction, so that the resultant revolutions are equal to $1 - \frac{c\,d}{b\,e}$, or $\frac{b\,e - c\,d}{b\,e}$, so that the total reduction of the train is equal to

$$\frac{c+a}{a} \text{ to } \frac{b\,e - c\,d}{b\,e} = \frac{\frac{c+a}{a}}{\frac{b\,e - c\,d}{b\,e}} \text{ to } 1,$$

which is equal to $\frac{b\,e\,(c+a)}{a\,(b\,e - c\,d)}$ to 1.

Taking an example in which A = 20, B = 40, C = 100, D = 39 and E = 99, we have:

$$\frac{40 \times 99\ (100 + 20)}{20\ (40 \times 99 - 100 \times 39)} \text{ to } 1,$$

or the tremendous reduction of 396 to 1. Taking examples of each of the three groups, with the pitch circle corresponding to 100 teeth as the maximum diameter and a minimum of 20 teeth in any wheel, we find that type 1 gives 6 to 1 reduction, type 2 gives 9 to 1, while type 3 gives 396 to 1. This latter type has not, to the writer's knowledge, been applied to any automobile purposes, and indeed such a reduction is hardly likely to be required for this work; but it might possibly be of service in some special application of Pelton wheels, steam turbines, etc. A fourth type, illustrated in Fig. 6, is somewhat different from those already dealt with; it forms a neat little arrangement, which can be stowed

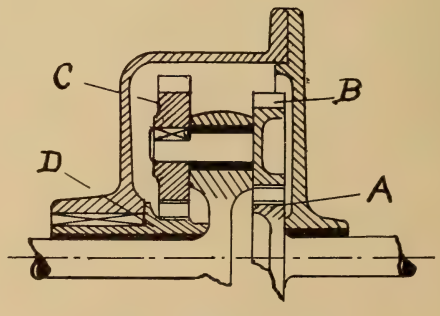


FIG. 6.—SPUR GEAR TRAIN

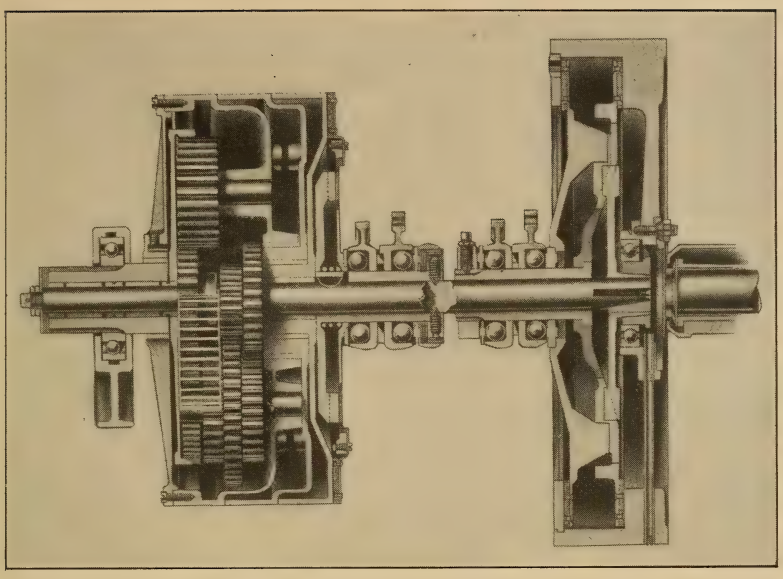


FIG. 7.—CADILLAC EPICYCLIC GEAR.

away in a very small space. Among other purposes, it has been used for working the feed of the cutter on machine tools, hand hoisting gear, coiling gear on colliery winding engines, etc. Its formula takes the following form: $\frac{c\,a - d\,b}{c\,c}$ to 1, and it has the merit that internal wheels are entirely absent, which is a distinct advantage, as the same degree of accuracy is rarely obtained with internal wheels as with external. We will now briefly touch on the application of these trains to some recent types of epicyclic change-speed gears on motor cars: (a) The Cadillac, illustrated in Figs. 7 and 8, transmits the power thus: A is driven by the engine, and on the reverse drives as an ordinary reduction through planet B, which is held stationary, into internally toothed wheel C, which is coupled to the Cardan shaft. The wheel B meshes with D, which is rigidly fixed to E and G, while these two latter wheels gear with F and H, respectively. First speed forward is obtained by wheels A, B, C, D, E and F, with F as fulcrum, forming a compound train of No. 4 type and following the formula: $\frac{c\,(e\,a + f\,d)}{a\,(e\,c - f\,d)}$ to 1. The second speed forward utilizes wheels A, B, C, D, G and H, with H as fulcrum, and forms a similar train to the first speed. The third speed forward is a through drive, obtained by locking the mech-

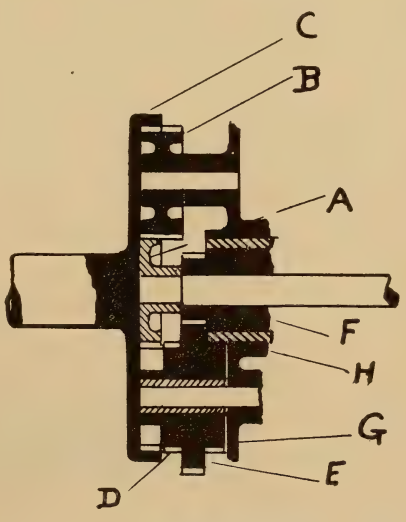


FIG. 8.—DIAGRAM OF CADILLAC EPICYCLIC GEAR.

anism and causing the whole to rotate as one mass.

The Adams-Hewitt two speeds forward and reverse gear-box is arranged as shown in Fig. 9. B, C, E are planet wheels, rigidly coupled together; the through drive obtained

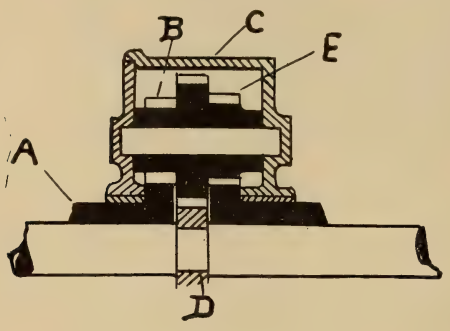


FIG. 9.—ADAMS-HEWITT GEAR.

by locking the mechanism is the top speed, and the other forward speed is obtained by preventing the planet from rotating round the sun, so that an ordinary compound reduction is given by D, C, B and A. The reverse is, therefore, the only epicyclic train in this gear box. F is the fulcrum wheel, and the train formed is a compound one of type 4.

Another excellently designed gear box is the Fairfax. The scheme illustrated in Fig. 10 has been designed for steam lurry work, and gives three speeds forward only. The engine drives the planet, which consists of C, G, E and A, all rigidly coupled together; internal wheel D is keyed to the last driven shaft, while the other internal wheels, H, F and B, form the fulcrum wheels for the three speeds. The gear is a modified form of type 2, D being an internal instead of external spur wheel, with the result that the gear gives a "negative" instead of "positive" rotation. The formula takes the form (using highest speed train A, B, C and D) 1 to $\frac{a\,d - b\,c}{a\,d}$, and it will be noticed that the resultant reduction is negative in sign, so that the three speeds are really three reverse speeds, the engine and last driven shaft rotating in opposite directions.

These three examples are typical of other types, so that it is unnecessary to deal with further specimens; it is, however, worthy of note that, speaking generally, the types in which the gears tend to give a negative rotation are slightly more efficient than those in which the gears give a positive rotation, e. g., type 3 will prove a slightly more efficient gear than type 1, other conditions, of course, being the same; the efficiency is also generally rather greater with

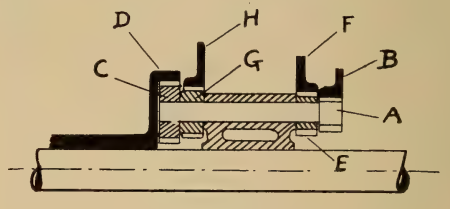


FIG. 10.—FAIRFAX GEAR

large reductions than with small, and the efficiency also slightly rises up to 20 horse-power. At this power a suitably designed 10 to 1 reduction gear of the gear-tending-to-drive-negatively type should give an efficiency of between 90 per cent. and 95 per cent.

THE UTILIZATION OF WASTE PRODUCTS

By F. F. Gairns

ONE of the "pass-words" of modern industry is: "Utilize waste products," there being a tendency to endeavour to make good use of every residue, surplus, by-product or other waste connected with most present-day manufacturing concerns.

Thus, to quote a few examples from general practice, a modern gas works provides material for various chemical manufactures; a large number of municipal electric light stations are combined with refuse destructors where the waste and refuse of the district are utilized for fuel in the boiler furnaces; cloth cuttings are employed in the preparation of certain fabrics; scrap iron and metal turnings provide the best metal for castings; used paper and old rags are largely employed for the manufacture of the commoner qualities of paper and cardboard; and so on one could go through every section of industry.

There are, however, several ways of looking at this subject from the purely commercial standpoint, in some cases not always favourable to the universal acceptance of "utilize waste products" as an industrial axiom, although as a rule there is no question as to the advisability of making good use of everything; and in the following remarks the writer briefly discusses some aspects of this important subject.

At the present time, after many years of the useful employment of trade waste, so many industries have been created or fostered as a result of this policy that it is very largely possible for any manufacturer to dispose of his waste or surplus material, whether large or small in quantity, on profitable terms to a dealer or manufacturer whose business requires or utilizes such material. When such is the case both parties are benefited—the one profitably gets rid of material that he does not want and that is only in his way, and the other obtains material for his own work at a reasonable rate. In many cases, however, the parties to such a mutually profitable arrangement are not so conveniently situated; either they are separated by considerable distances, and freight charges seriously affect the profit of the deal, or one party has more material to sell than the other can take, or the one requires more material than he can obtain.

As a rule, the latter state of affairs adjusts itself with time, and is sometimes actually more profitable, for the purchasing manufacturer who can stock material in quantities may be able to buy cheap, or the selling manufacturer can dispose of his waste at an enhanced price owing to its scarcity. But when the matter of freight cost is the difficulty, it becomes a moot question whether waste material is a source of trouble and expense or of profit. In fact, it often occurs that, instead of waste material having a selling value, the "purchaser" (*sic*) requires to be paid to remove it, although the material is itself a source of profit to him.

So far, we have considered only the cases where the manufacturer who has waste to dispose of cannot deal with the material himself, but is dependent upon a dealer who can profitably take such material.

In all the established sections of industry both parties to a deal of this

kind are available unless geographical location, transport difficulties, and the like, minimize the profits of the transaction or render the disposal of waste products a matter of expense instead of profit. But when only one party to the deal is available—the manufacturer having waste material to dispose of—it becomes a question how the material is to be profitably utilized. Sometimes the principal profit lies in getting rid of the stuff, in which case, unless the manufactory concerned is in an isolated neighbourhood and good dumping grounds are available, the chances are that the manufacturer would otherwise get into difficulties with municipal or other authorities for fouling a river or otherwise endangering public health, or usurping public rights in some way. In such instances the man who will remove the material is a benefactor, even if he has to be paid for doing so, and the selling party obtains his "profit," because he can dispose of the material with less cost to himself than would be the case were the material of no use to any one.

The other alternative is to introduce a private plant for dealing with one's own waste material; and on a large scale this may prove very profitable. In fact, there are cases on record where the industry introduced in this way has created a market for itself, and the new business has dwarfed the old. On the other hand, it has occurred as often that the new business has killed itself, owing to the fact that, as soon as waste material comes to be in request, this same material becomes valuable and proportionately costly—so much so, in some cases, that it ceases to be profitable to utilize it at all. This usually occurs where the special plant demands more material than the original business can supply and additional material has been purchased.

A notable example of this state of affairs is provided by the use of oil fuel on the Great Eastern Railway of England. For many years a considerable number of locomotives were fitted for oil burning; but instead of about a hundred of them being in use, as was the case five or six years ago, they now total only about twenty. The reason is, that oil burning was first introduced by Mr. Holden to utilize waste material from the plant used for supplying oil-gas for carriage lighting, owing to the fact that the River Lea Conservancy objected to the offensive material being emptied into their waters. But a very few engines could use all the available material, so that the extension of oil burning required the purchase of material elsewhere. As a result, what was originally waste came to have a value, and the writer understands that it is now cheaper to use coal for the engines.

Similar cases can be quoted in connection with most industries where the useful employment of waste products has created an industry and, to a large extent, defeated its own ends. It is true that, in many instances, it is still profitable to carry on a waste-utilization plant, merely because the material is got rid of; but in other cases, especially if such a plant requires additional material to keep it going, it may be a source of actual loss after the first two or three years.

As regards the introduction of new industries in the attempt to deal usefully with waste products, it is usually the first manufacturers in the field who obtain most benefit, for their followers have less opportunity for profit, as the material employed has obtained commercial value by the time they commence business, while the originators have obtained the best of the trade in the new product, and will keep it so long as they maintain the quality and conduct their affairs in a businesslike and rational manner.

From the foregoing remarks, for which no particular novelty is claimed, and which only skirt the fringe of our subject, it will be seen that the real profitableness of the utilization of waste products is sometimes more

apparent than real, and, however desirable as representing progress, practice sometimes defeats its own ends, and what is intended to prove a source of profit may, after a time, become a source of loss. On the whole, however, the utilization of waste products is to be commended, and may become the nucleus of a good business. Also it must be remembered that, although an industry of this kind may be started to provide a profit that is only realized for a short time, the profit disappearing when the industry becomes general, on the other hand such industries become staple, and new industries of corresponding character arise in the course of time—maybe from the one already introduced—to carry on the chain of progress.

Our subject may now be summarized, partly in connection with the above remarks and partly in combination with additional ideas:

(a) The utilization of waste products is inevitable as a feature of industrial progress.

(b) By its practice two purposes are served:

(1) Surplus and waste material is utilized more or less profitably.

(2) A new industry is created.

(c) The profit, as regards disposal, may arise from the same causes.

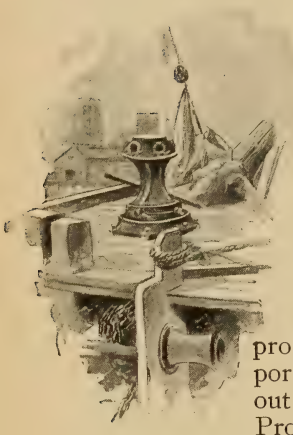
(d) The utilization of waste material causes a demand therefor, and dealers or manufacturers arise who will purchase, or remove at reasonable cost, material that other manufacturers wish to dispose of, either with profit or at the least expense.

(e) If special and extensive plant is required for such utilization of waste products, work on a fairly large scale is generally necessary, and after the first period such utilization is only profitable on ordinary business lines.

In conclusion, it must be said that, before a manufacturer introduces a waste-utilization process and plant, it is not merely the present conditions of affairs that has to be considered, but the future has to be looked to carefully. If the serving of present purposes is all that is required, then things may be conducted as may be most convenient at the time; but it is usually best for a waste-utilization industry to be conducted on its own merits as a branch of the originating business, or established as an independent concern.

CONSTRUCTION WORK ON THE ERIE BARGE CANAL

By James Cooke Mills



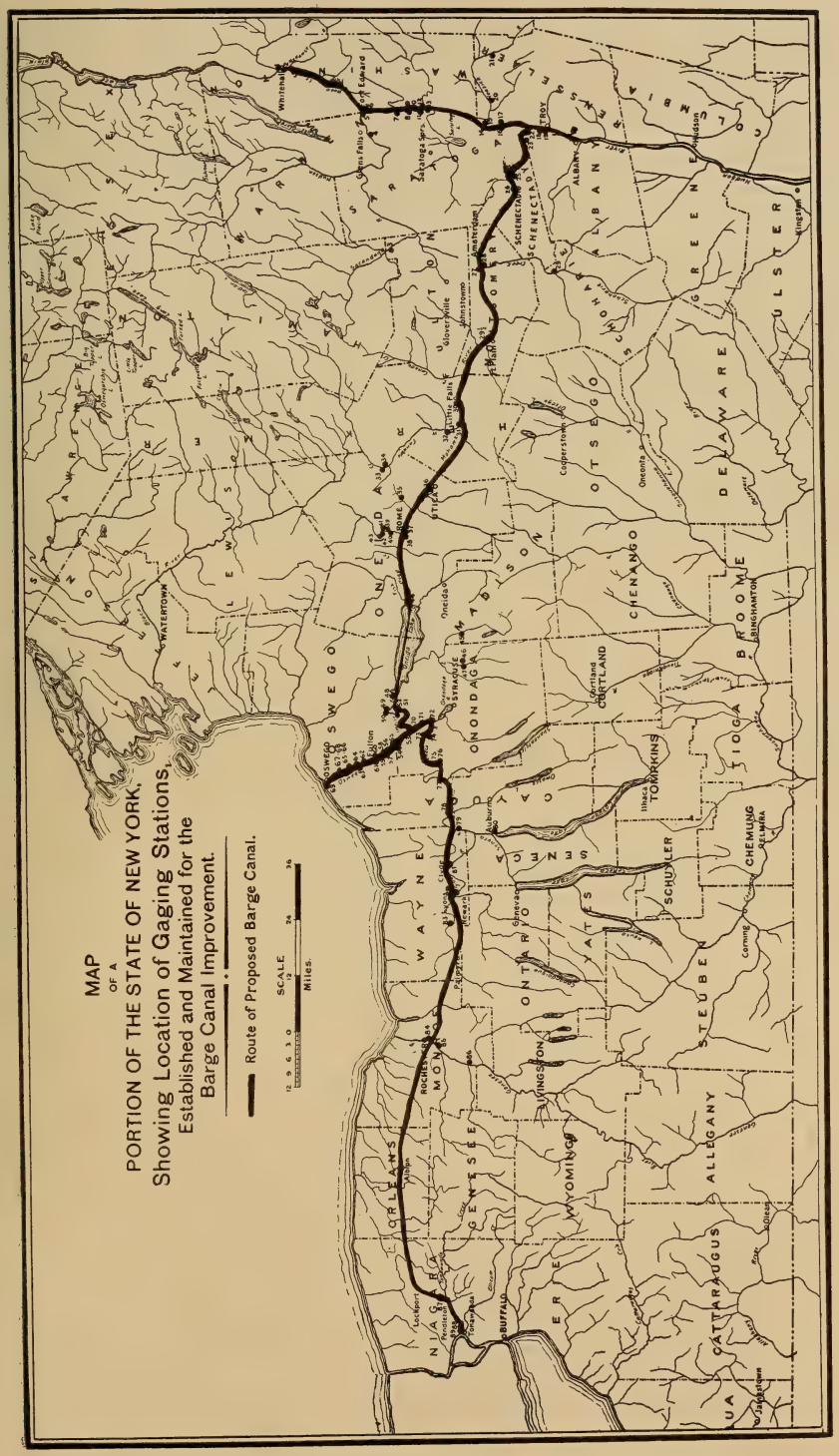
OF the two great American engineering enterprises of this decade, the Federal project—the Panama Canal—for many reasons, looms so large in the public eye as to almost obscure the other project of national importance being carried out by one State alone. Probably the majority of the people in the State in which the Erie Barge Canal is being built are unaware of the fact that, in the mere magnitude of the work to be done, the New York canal exceeds that at Panama.

This statement, which is verified by a comparison of the amounts of excavation necessary in the two projects, is all the more susprising when the estimates of cost of each are considered, inasmuch as the Barge Canal is expected to require an outlay of $101,000,000, while the expenditures on the Isthmian Canal will eventually reach a sum nearly three times greater.

This great difference in cost is due only to the fact that the unit prices that must be paid for work at Panama are so much higher than those done at home, and in a temperate zone. All the machinery, tools, supplies and the workmen must be transported long distances to the scene of operations at Panama. Furthermore, the scale of wages in the torrid zone is much higher and the efficiency of the worker is much less than in the northern State. Many millions of dollars have been expended on the isthmus for sanitation, proper housing for the army of workmen and for improvements in the towns of Panama and Colon, as well as betterments to the Panama Railroad, of which the government is practically the sole owner.

The Barge Canal has been planned to accommodate a tonnage of ten millions per year, while at a slightly greater cost a very much larger tonnage can be provided for. The commerce of the Great Lakes exceeds one hundred million tons yearly, and the importance of the enlarged canal lies in the fact that it will provide a means for connecting this huge commerce with the sea coast by a direct route, on which freight can be carried at a cost below that which is possible on a railroad.

The present Erie Canal is about 350 miles long, and of this distance the Barge Canal follows the old route for only 24 per cent., or 84 miles. For the other 260 odd miles the canal is laid out on what is practically another route. This is explained by the fact that while the Erie Canal clings to the lower slopes of the hills, well above the rivers, the new canal, which is much wider and deeper, is located in the valley bottoms, and follows largely the rivers and lakes. It is an historical fact of no little interest that the location of the new canal follows very closely an old route of travel by water, which was used by the pioneers who settled the western part of the State.



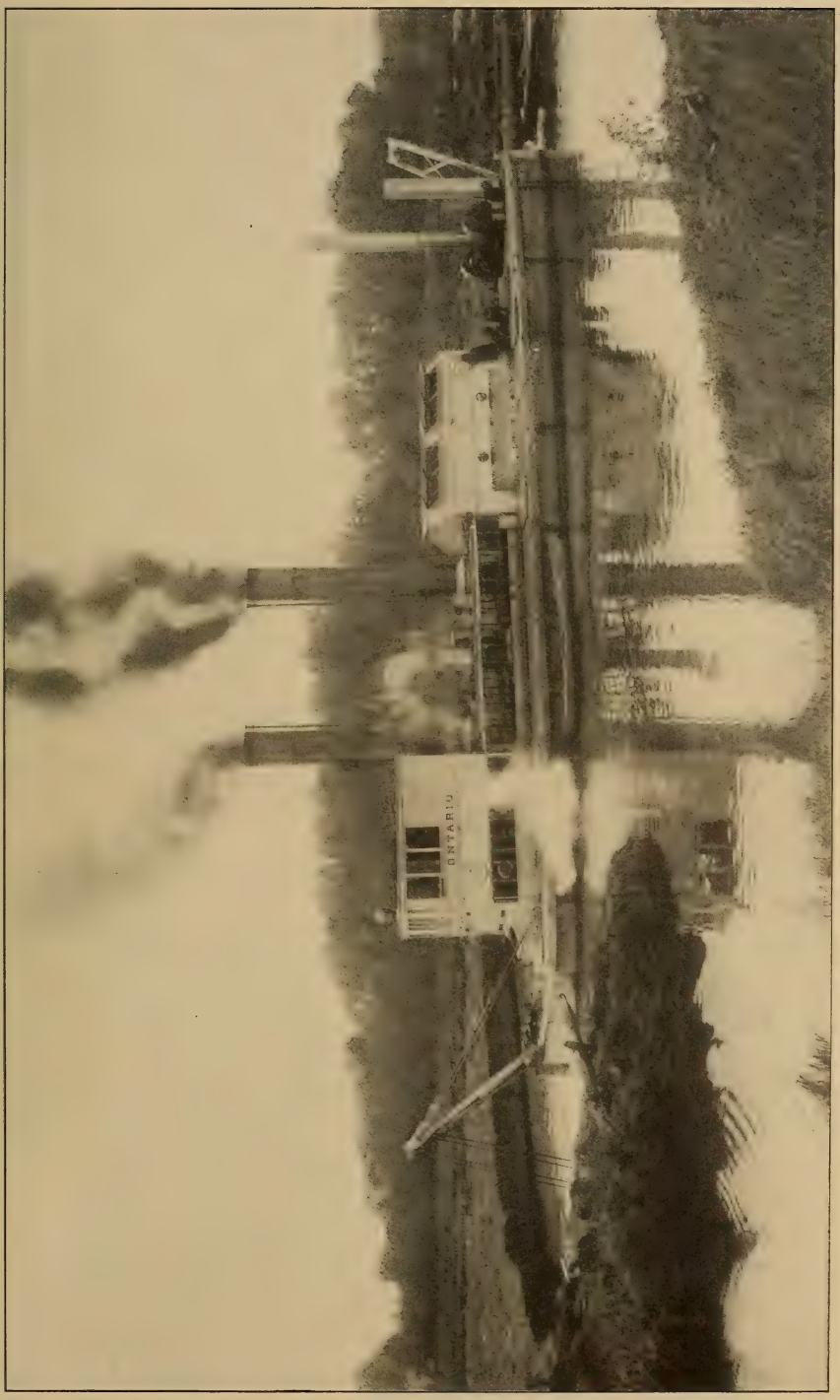
MAP OF THE ERIE BARGE CANAL.

VIEW OF STEEL HYDRAULIC SUCTION DREDGE UNDER CONSTRUCTION.

The early pioneer water-route, upon leaving the Hudson at Albany, lay up the Mohawk River to the vicinity of Rome, where a portage was made to Wood Creek, which was followed to Oneida Lake. After crossing the lake the route lay down the Oneida River to the junction of the Oswego and Seneca Rivers, at Three Rivers Point. If from this point the traveler were bound for the settlements in the western part of the State, he followed the Seneca River, or if he were making for Canada or the Far West, he followed the Oswego River to Lake Ontario and continued his journey by the Great Lakes.

When the Erie Canal was built, in 1817 to 1825, its builders adopted the European practice of that time, and, so far as possible, avoided the old water courses; but the new Barge Canal will follow them with but slight deviation. The new route lies along the Hudson River to Waterford, then, by a series of six locks, passes above Cohoes Falls to the Mohawk River, the elevation above the Hudson being 184 feet. From the falls to the Rome summit level, a distance of 100 miles, the bed of the stream is utilized, the river being canalized by a system of pools formed by movable dams. There are to be eight of these dams, of the Boulé gate type, each provided with a lock having a maximum lift of 20 feet. Beyond Rome the summit level, or divide of the water-sheds of the Hudson and Ontario, is cut through to Wood Creek, and the canal then continues over the old pioneer water-route up the Seneca River to the neighborhood of Clyde. From there the new canal follows the route of the Erie to the Niagara River at Tonawanda. The Oswego branch canal leaves the Barge Canal at Three Rivers Point and utilizes the canalized Oswego River to Lake Ontario. The Champlain branch uses the Hudson River bed from Waterford to Fort Edward, and from there to Lake Champlain the present canal location is followed.

The original Erie Canal was 40 feet wide on the surface and had a depth of 4 feet, accommodating boats of only 80 tons capacity. During the period from 1835 to 1862 the canal was enlarged to a width of 70 feet and a depth of 7 feet, to take boats up to 240 tons burden. In the seventies and eighties many improve-

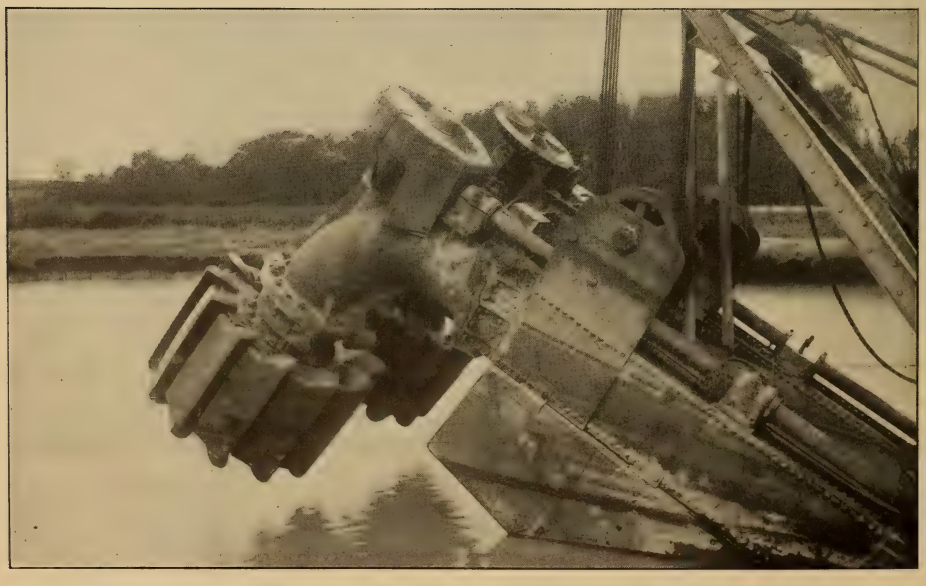


ERIE BARGE CANAL. STEEL SUCTION DREDGE AT WORK. EMPIRE ENGINEERING CO., NEW YORK.

ments were made in locks and canal prism, and many of the old bridges across the canal were replaced with larger and higher ones. In 1894 the agitation for deepening to 9 feet resulted in the famous nine million dollars appropriation, which proved to be absurdly inadequate, entailing a further appropriation of sixteen millions to complete the enlargement. Finally the present scheme was adopted, which provides for a canal 123 feet wide on the surface, 75 feet wide on the bottom, and with a uniform depth of 12 feet. The locks, of which there are thirty-nine provided for between Waterford and Tonawanda, are to be 328 feet in length between hollow quoins, 45 feet in width, and with a minimum depth of 12 feet on the miter-sills. These dimensions are ample to accommodate two 1,000-ton barges—a steam barge and one of the tow—at one lockage, which is about eight times the capacity of the present canal.

Some interesting machinery has been installed along the various sections of the canal, especially in the vicinity of Oneida Lake, where the quantity of excavation required reaches enormous proportions. Along Oneida River the sharpest bends are being eliminated by cutting new channels through the points of land, and the river is being deepened to Three Rivers Point (No. 53 on map). The excavation on these contracts is of such a character as to require large and specially designed dredges, which had to be built and erected on the site of the work, inasmuch as the existing waterway connecting with the Great Lakes was not adequate to float them.

These dredges, as shown in the illustrations, are of the hydraulic type, and are built in three sections. There is a centre sponson of steel, containing the boilers and machinery, which is of the most powerful and approved design, and a lighter section on each side, all held securely together as one body. The huge cutting apparatus in the bow of the dredge is a most novel and interesting feature, and was designed by Lindon W. Bates, C. E., of the Empire Engineering Company, contractors for much of the work in this section. The entire cutting mechanism is hung on flexible joints, so that it may be adjusted to the vary-



REVOLVING CUTTERS OF HYDRAULIC DREDGE ONTARIO, RAISED FOR CLEANING AND INSPECTION

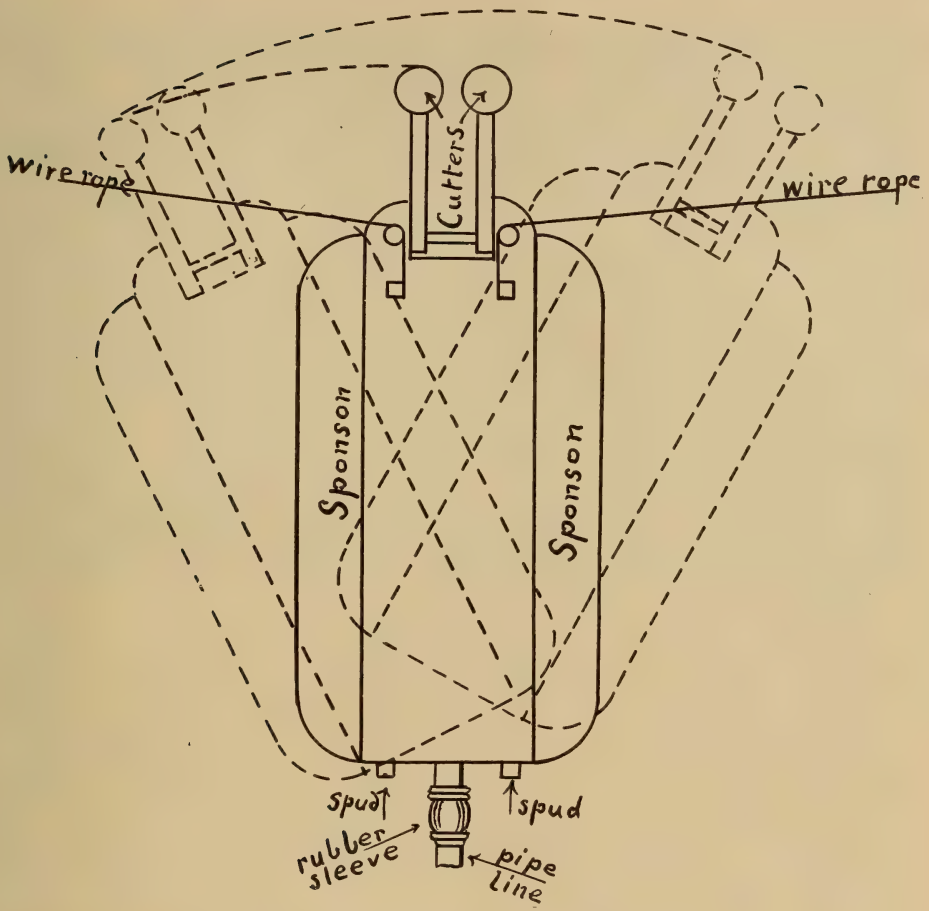


DIAGRAM SHOWING OPERATION OF HYDRAULIC DREDGE.

ing depth of the material to be excavated, or raised clear of the water for cleaning and repairs. As shown in the cut, the ends of the suction pipes terminate in series of long, flat knives, arranged in the form of drums, which are hung on shafts running through the centre of the pipes. When the apparatus is lowered beneath the surface of the water, the sand and clay formations, cut by the rapidly revolving knives, melt away in the swirling water, and the solution is sucked in by powerful centrifugal pumps.

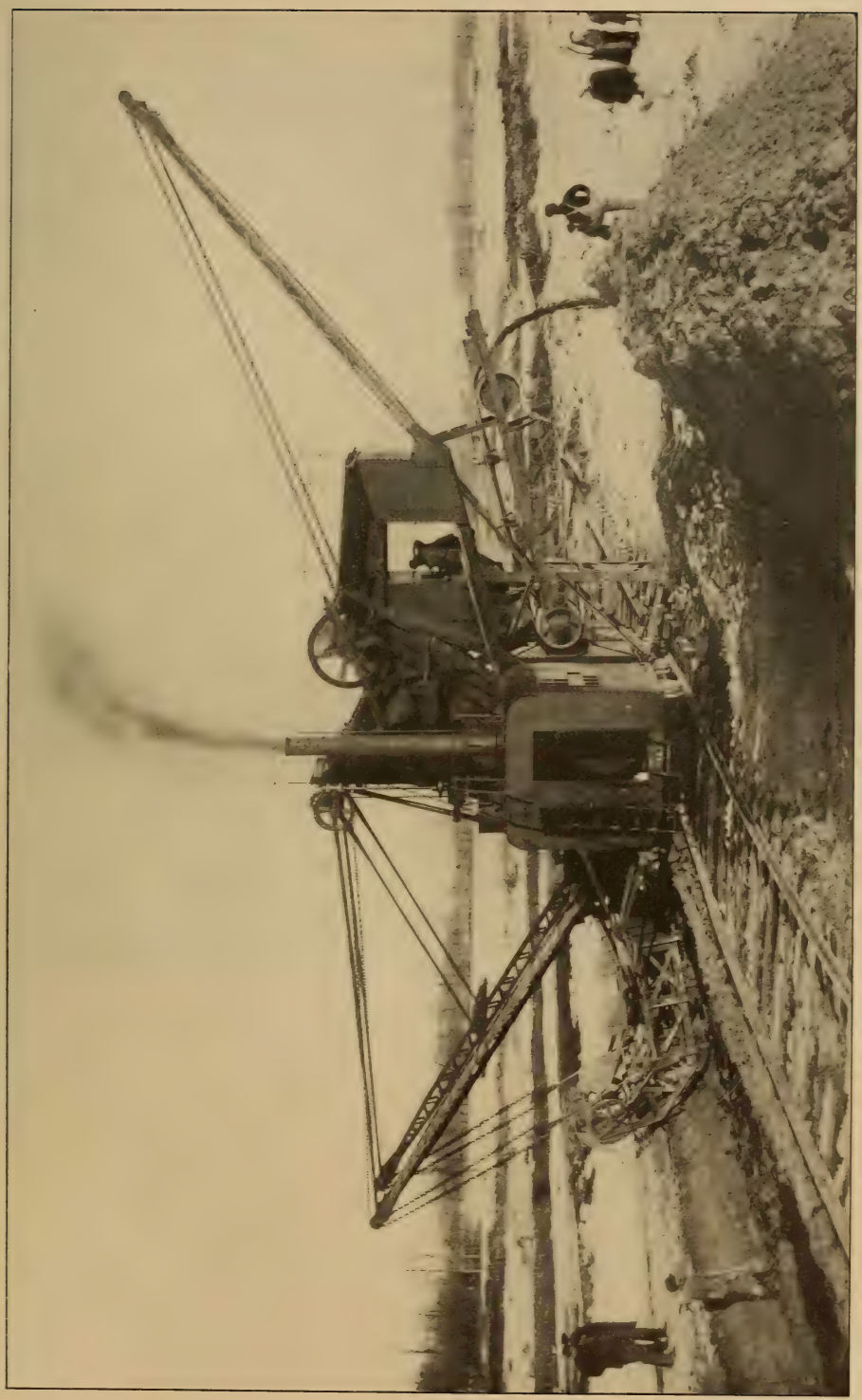
The spoil pipe line leaves the dredge at the stern, and is carried on a series of pontoons some distance to the dump. Rubber sleeves between the dredge and first pontoon, and between the pontoons themselves, permit of various movements of the dredge as it gradually forces its way into the soil of the canal route. The diagram shows how the dredge swings from side to side and thus secures new material for its voracious cutters, and at the same time effecting a steady onward movement. The dredge is lying in the middle of the prism and, in order to excavate the required depth the full width of the canal, drops spud No. 1 into the bottom soil. The wire ropes are securely anchored on either bank, and by the left winding drum the dredge is slowly swung around as far as it will go, in the meantime cutting out the shorter segment. In its new position spud No. 2 is dropped

INTERIOR OF CONTROLLER ROOM ON HYDRAULIC DREDGE.

and No. 1 is raised. Releasing the left wire rope on its drum and winding on the right drum swings the dredge to the extreme right bank, cutting its way as it proceeds. Continuing this swinging operation, the "Ontario" advances through sand and clay at a rate of 100 to 150 feet every twenty-four hours. When gravel and stone formations are encountered, an ordinary bucket dredge is used for such material, and in some places is also used to trim up the edges and bottom.

Several compartments of the sponsons are used as settling tanks for the feed-water for the boilers, to purify the muddy water before using it. Oil is used for fuel, and is found much more satisfactory than coal. The initial cost is greater by about 5 per cent; but when the saving in wages of stokers is taken into account, the final cost is somewhat less. The men working these dredges are divided into three shifts of eight hours each, and the tricks are arranged from eight to twelve, twelve to four, and four to eight. There is no delay on account of wet weather, the dredges working as well in the pouring rain as when the sun is shining fiercely on the scene. The suction dredges, where there is water to float them and the pontoons for the pipe lines, effect a large saving in excavation work, especially where the soil is free from rock and gravel.

To prepare a dyke, behind which the spoil from the dredge is deposited, a Lubecker trencher is used. It has been called "the hybrid of excavators," and its appearance at all times, whether "dead" or in operation, fully accounts for the term given it. On many contracts along the canal route, where dry excavating is more economically done, the Lubecker is marvelously efficient. The machine digs a trench and, carrying the earth 20 to 40 feet, as the case may require, deposits the spoil in a regular bank. On the left an endless chain of buckets digs up the earth in huge spoonfuls and, conveying it through the body of the machine, drops it on an endless belt, which, in turn, dumps the earth far out on the right. The chain and belt are raised and lowered, or extended as desired by long-arm cranes stretching out on both sides, giving the machine the appearance of some huge vulture carving out a deep rut in the earth. The ma-



THE LUBECKER TRENCHER AT WORK ON THE ERIE BARGE CANAL.

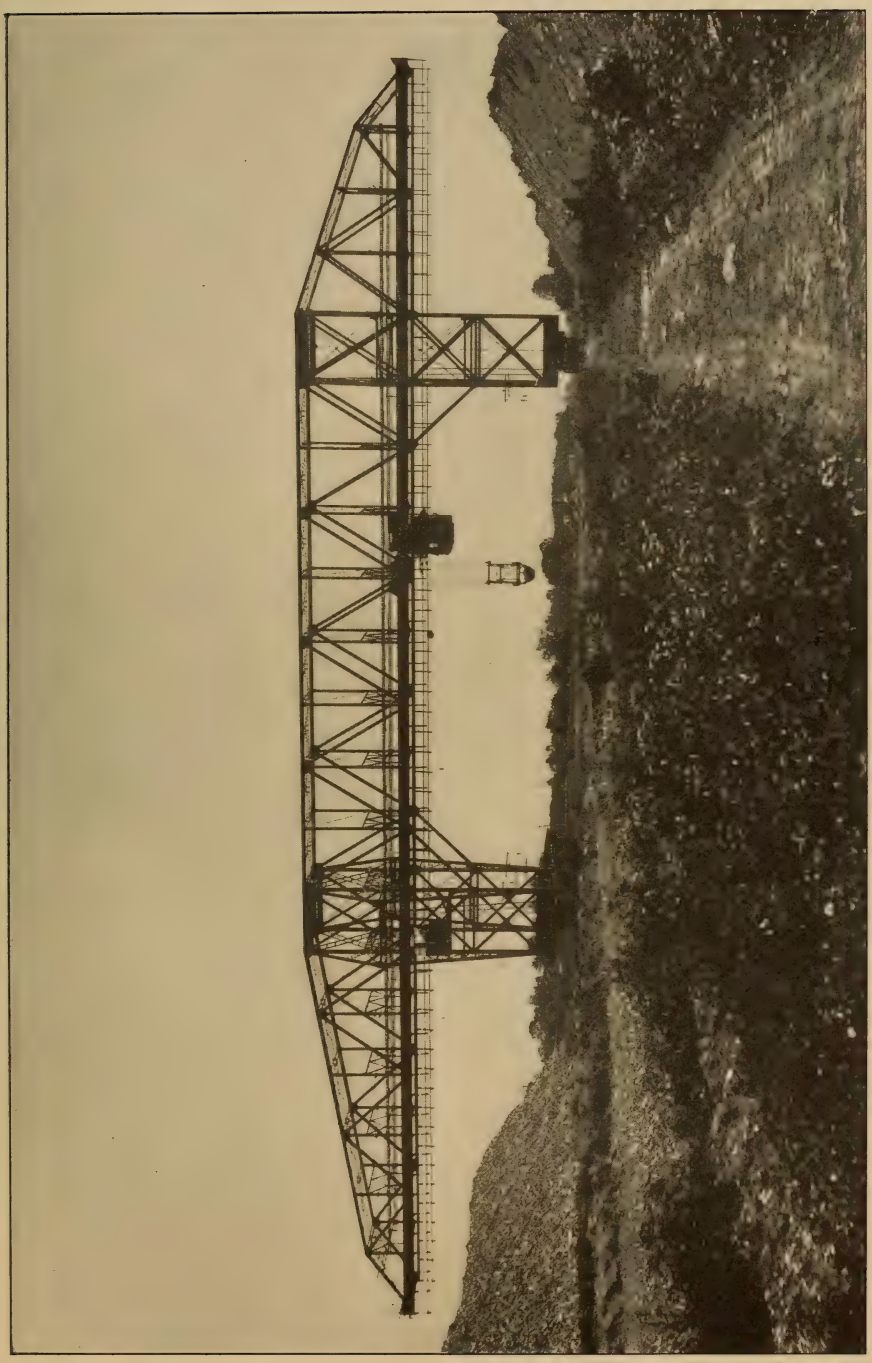
chine has the advantage of permitting work of its kind during the winter months, and, in cut 5, the crust of frozen ground, fully 8 to 10 inches thick, is plainly noticeable. Working under the usual conditions in any soil other than rock, the Lubecker's normal capacity is 100 cubic yards per hour. Near Sylvan Beach, at the east end of Oneida Lake, the trencher has cut a wide ditch eastward for several miles, thus blazing the way, as it were, for the dredges following after.

On the western division, near Rochester, there is a stretch of over

ERIE BARGE CANAL. HYDRAULIC DREDGE EXCAVATION.

two miles of heavy cutting, where a huge machine of unusual proportions and design for excavating is being used with good results. It is a truss machine, utilizing the principle of the grab bucket to excavate material from the canal bed. The truss is over 425 feet long and 56 feet high, with the two tower bases mounted on heavy trucks, designed to travel on standard gauge tracks, one on each side of the cut. The total weight of the machine is 350 tons, and it operates a bucket of 8 cubic yards capacity, designed to load automatically with earth, which has been well broken up. In the cab placed directly under the truss the operator governs all movements of the bucket and the advance of the machine itself, while a foreman and six labourers attend to the ground work.

The machine is electrically driven by power from Rochester, which accounts for the small gang needed for its operation, which is simple, yet positive. The grab bucket, with its wide-open jaws, is dropped a number of feet into the loose earth, partly burying itself by its momentum. The scoops of its huge jaws are then drawn together by a mechanism actuated by wire ropes wound on drums in the traveler overhead. The operator then sets the crane motors at work lifting the bucket and its load 30 or 40 feet clear of the ground. By application of power to still other motors, the traveler, with its suspended bucket, runs along a track to the end of the truss, where the tons of earth are deposited. When the machine was first operated, however, it was found that no more than two or three cubic yards could be

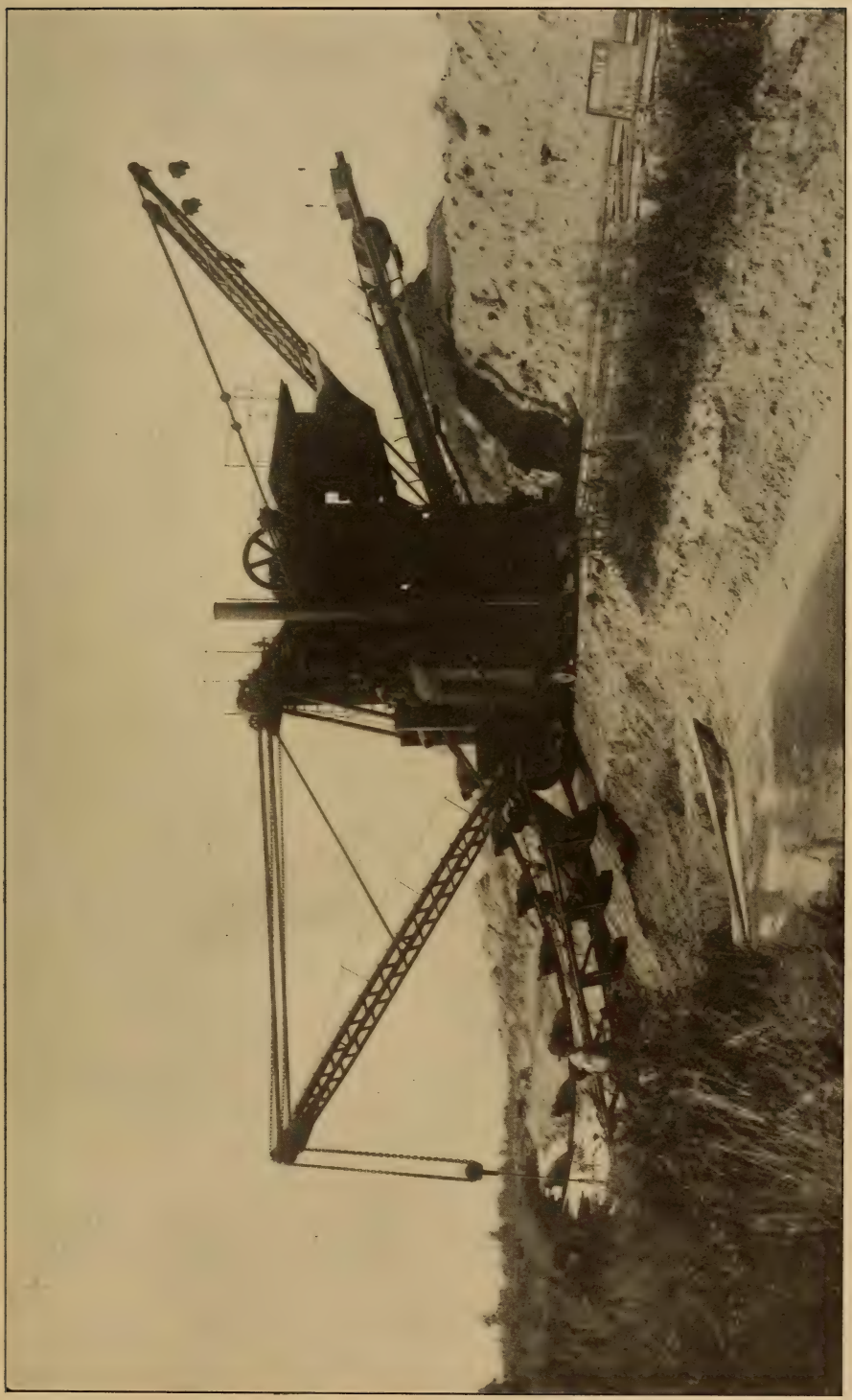


ERIE BARGE CANAL. GRAB-BUCKET MACHINE EXCAVATING PRISM AND DEPOSITING SPOIL ON SIDE BANKS. DRIVEN BY ELECTRIC POWER TRANSMITTED FROM ROCHESTER.

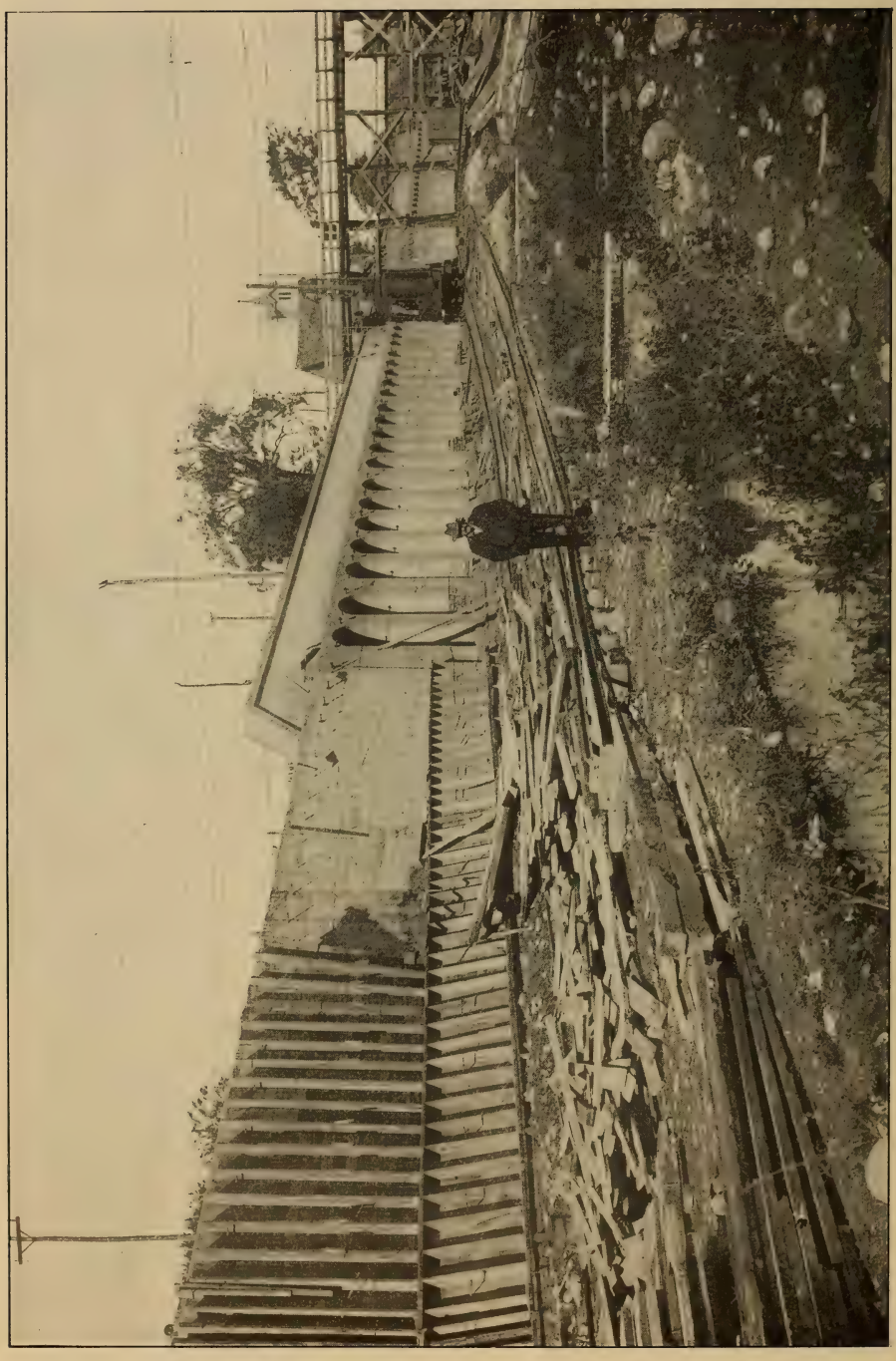
DROP ROCK CRUSHER AT WORK NEAR BUFFALO. EMPIRE ENGINEERING CO. NEW YORK.

grabbed by the bucket in tough clay formations, consequently a steam shovel was installed to load the bucket, the grab still being continued to strip the earth surface. Experience with the grab bucket type of excavator has demonstrated that the truss machine cannot be a paying proposition except on contracts having a long stretch of continuous operation.

Along the Niagara River and in Buffalo harbour millions are being expended for needed improvements to the channels and in the construction of an immense lock, 650 feet in length, 70 feet in width, and with a depth of 24 feet on the sills. This lock marks the western end of the canal proper, forming, as it does, the real gateway to Lake Erie. The first section of the deep channel, 23 feet in depth and 400 feet wide, extends from Maryland street, Buffalo,



ERIE BARGE CANAL. PRISM EXCAVATION WITH LUBECKER TRENCHER NEAR STATION 6800.



CONSTRUCTION OF CONCRETE RETAINING WALLS ON THE ERIE BARGE CANAL.

ERIE BARGE CANAL. CONCRETE ABUTMENTS FOR SYLVAN BEACH BRIDGE.

to a point a mile and a quarter below, which is nearly opposite Fort Porter. The contract on this section, it is expected, will be completed by December 31, 1908. A dipper dredge strips off rock bed, which is extremely hard and solid, and must be broken before it can be removed.

To accomplish this, the Empire Engineering Company has built a rock crusher of curious construction, as shown in the reproduced photograph. At the front of the scows, and directly under the high shears, is a shaft of steel, which is raised by hoisting engines and dropped 6 or 8 feet onto the rock below. The points of the crusher, when first put in use, caused much trouble; but the difficulty in getting proper material for them has been overcome, and the points now used are capable of standing 25,000 blows. The dipper dredge has a capacity of filling a 600-cubic-yards scow in two and a half hours.

When the evidence of the enormous mechanical energy combined in these powerful and highly efficient excavators is brought in comparison with the simple and primitive devices of the early canal-builders, who dug practically all of the original Erie with the wheelbarrow and shovel, the wonder grows that the waterway, as small as it was, could have been completed in only eight years. It was a wonderful achievement for those times, considering the financial difficulties and the physical problems incident to digging a canal through almost unbroken forests and along uncontrollable rivers for 350 miles into the heart of the then Far West. Before very long it will be known whether or not the present builders, with ample funds and powerful machinery, will be able to do as well.

INLAND WATERWAYS IN THE UNITED STATES

AN ABSTRACT OF THE PRELIMINARY REPORT OF THE INLAND WATERWAYS COMMISSION.

ABOUT one year ago there was created by the President of the United States a commission for the purpose of preparing a comprehensive plan for the improvement and control of the river systems of the United States, this subject including the improvement of navigation, the development of power, the irrigation of arid lands, the protection of lowlands from floods, and the provision of water supply for domestic and manufacturing purposes.

The preliminary report of this commission has been transmitted to Congress by the President, and as certain portions of this report are closely connected with important departments of engineering work it has been thought advisable to publish an abstract of this important document in this place.

This whole question forms but a portion of the present movement towards the development of a national policy for the conservation of the natural resources of the country, and for the prevention of the unrestricted waste which has hitherto prevailed, not only of actual material resources, but of potential wealth in the shape of flowing water, avenues of transport, and the like.

The preliminary report of the commission is confined to the principles affecting the whole problem, the details to be considered hereafter by experts in the different lines of work involved, the special feature most strongly emphasized being the development of waterways for transport. This, however, must include much of the investigation involved in the development of hydraulic power, a question again closely allied to the insulation of hydro-electric power stations, and the transmission and distribution of the power thus generated, so that the far-reaching scope of the work of the commission will be realized.

The general findings of the commission are as follows:

The possibilities of inland navigation are indicated by the fact that there are in mainland United States some 25,000 miles of navigated rivers, and at least an equal amount which are navigable or might be made so by improvement; there are also some 2,500 miles of navigable canals, and over 2,500 miles of sounds, bays and bayous readily connectable by canals aggregating less than 1,000 miles in length to form inner passages paralleling the Atlantic and Gulf coasts—these being additional to some thousands of miles (reckoned between leading ports) of regularly navigated waters in lakes and landlocked bays. These waterways lie in or along the borders of Alabama, Arkansas, California, Connecticut, Delaware, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, New Hampshire, New Jersey, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Vermont, Virginia, Washington, West Virginia and Wisconsin, *i. e.*, forty-two States; while the de-

velopment of rivers for irrigation, power, and other purposes will also render navigable certain waterways in Arizona, Colorado, Nevada, New Mexico, Utah and Wyoming. Although it is not probable that any considerable share of this vast mileage of navigable waterways will be improved to a high standard of efficiency, at least at an early date, yet the assured growth of the country and the capacity of these waters, not only for navigation, but for other uses, render imperative the necessity for their control and utilization as an asset of almost unlimited value. It is desirable that these waterways, of which portions have been surveyed or improved for purposes of navigation, should be further investigated with a view to the systematic development of inter-State commerce in co-ordination with all other uses of the waters and benefits to be derived from them.

While the railways of mainland United States have been notably efficient in extending and promoting the production and commerce of the country, it is clear that at seasons recurring with increasing frequency they are unable to keep pace with production or to meet the requirements of transportation.

While navigation of the inland waterways declined with the increase in rail transportation during the later decades of the past century, it has become clear that the time is at hand for restoring and developing such inland navigation and water transportation as upon expert examination may appear to confer a benefit commensurate with the cost, to be utilized both independently and as a necessary adjunct to rail transportation.

While the decline of navigation in the inland waterways was largely due to the natural growth and legitimate competition attending railway extension, it is also clear that railway interests have been successfully directed against the normal maintenance and development of water traffic by control of water-fronts and terminals, by acquisition or control of competing canals and vessels, by discriminating tariffs, by rebates, by adverse placement of tracks and structures, and by other means.

Any complete or practically successful plan for the general improvement of waterways must eventually provide for satisfactory adjustment of the relation of rail lines to such waterways. Since present and prospective railways reach all parts of the country, while navigable waterways are confined to certain natural lines, it is clear that railways can so control transportation as to leave the waterways insufficient traffic to support the requisite vessels and terminals. The railways have, accordingly, save in certain exceptional cases, substantially absorbed the traffic of the country, and unless the present unrestricted and short-sighted competition between the two systems is intelligently adjusted they will continue to do so. So large a portion of railway traffic is free from water competition that railways can readily afford to so reduce rates on those portions affected by such competition as to destroy the profits of the water lines without appreciably affecting the profits of the rail systems which recoup these reductions by higher rates elsewhere. This has been the case with most of the great inland waterways, excepting the Great Lakes, where the conditions of water and traffic approach those of open seas. In spite of the great increase of traffic and the continued improvement of waterways, the total river traffic of the country has steadily decreased both proportionately and absolutely, with the result that few rivers are used to anything approaching their full capacity. It will not relieve traffic congestion to improve our waterways unless the improved waterways are used; hence it is obvious that relief from the existing congestion by waterway improvement can be made permanently effective only through such coordination of rail and water facilities as will insure harmonious co-opera-

tion rather than injurious opposition.

Existing data as to the nature and amount of the internal commerce of the country are extremely meager and incomplete. Such information is essential to the intelligent treatment of the inland waterways, and it is desirable that means be employed to obtain it.

Improvements of navigation in inland waterways, in the main, affect favorably the purity of the waters and the regularity of the supply, and these objects should be carefully kept in mind. The increasing pollution of streams by soil-wash and other waste substances, connected with a growing population, reduces the value of the water for manufacturing purposes, and renders the water-supply for communities injurious to, and often destructive of, human life. The prevention of these evils should be considered in any scheme of inland waterway improvement.

Engineering works designed to improve navigation affect favourably the regimen of the streams, including floods and low waters. The annual floods of the United States occasion loss of property reaching many millions of dollars, with considerable loss of life, while the low water of late summer involves large loss in diminished water supply, in reduced power, and in the fouling of streams, with consequent disease and death. It has been claimed that in specific cases the cost of works required, both to control floods and meet the needs of commerce, would be less than the amount of this loss. It is desirable that more detailed information be collected concerning the effects of floods and low waters and their prevention by engineering works and other devices.

The annual soil-wash in mainland United States is estimated at about a thousand million tons, of which the greater part is the most valuable portion of the soil; it is carried into the rivers, where it pollutes the waters, necessitates frequent and costly dredging, and reduces the efficiency of works designed to facilitate navigation and afford protection from floods. The direct and indirect losses from this source have not been measured, but are exceedingly large; and it is desirable that definite determinations be made with the view of devising means for reducing the loss to the land and preventing the impairment of the streams for purposes of commerce.

Both the regimen of streams and the purity and clarity of waters are affected by forests and other natural growth, and by farming, mining, and other industrial operations over the watersheds in which they gather. Millions of acres in mainland United States have been deforested unnecessarily, and the floods and low waters ascribed to this cause have in some localities occasioned losses commensurate with the value of the timber. Means should be devised and applied for co-ordinating forestry, farming, mining and related industries with the uses of streams for commerce and for other purposes.

The effect of wide variations in the level of navigable streams is to render difficult the establishment of necessary terminals for the handling of traffic, and thus to interfere seriously with the utilization of our inland waterways. The prevention or mitigation of such variations would be most helpful to the revival of river traffic, and means to this end should be adopted in plans for waterway improvement.

The storage of flood waters combined with the diversion of streams to arid and semi-arid lands for purposes of reclamation by irrigation creates canals and also tends to clarify the waters and increase the seepage or return waters during times of drought. There have already been put under irigation over 10,000,000 acres of fertile land, adding a quarter of a million homes and several hundred million dollars of taxable wealth; and it is estimated that by fully conserving the waters and by utilizing the water-power developed in connection

with storage and other works, fully three times as much land can be reclaimed in the Western half of the United States. It is desirable to continue the collection of data with a view to so adjusting irrigation and power development with navigation and other uses of the streams as to secure the highest value of the water to the greatest number of people.

Locks and certain other works designed to improve navigation commonly produce head and store water in such manner as to develop power available for industrial purposes, while works designed to develop power on navigable and source streams affect the navigation and other uses of river systems; and these uses must necessarily be considered together. Information concerning water-power in the several States and sections is incomplete, yet it is known to be a vast and intrinsically permanent asset which should be utilized for the benefit of the people of the country, in whose interests it should be administered with careful regard for present and prospective conditions. The facts ascertained in certain specific cases furnish a basis for the claim that the value of the power would pay the cost of all engineering and other works required in such cases to control the streams for navigation and other uses. In the light of recent progress in electrical application, it is clear that over wide areas the appropriation of water-power offers an unequalled opportunity for monopolistic control of industries. Whereever water is now, or will hereafter, become the chief source of power, the monopolization of electricity produced from running streams involves monopoly of power for the transportation of freight and passengers, for manufacturing, and for supplying light, heat and other domestic, agricultural and municipal necessities, to such an extent that unless regulated it will entail monopolistic control of the daily life of our people in an unprecedented degree. There is here presented an urgent need for prompt and vigorous action by State and Federal Governments.

Any comprehensive system of improvement of inland waterways will necessarily affect the drainage or reclamation of swamp and overflow lands, which are mainly rich alluvial tracts largely along or near waterways. The construction of dikes and levees or bank-protective works and the deepening of channels are often closely connected with means of control both of overflow and of underflow by drainage. It is estimated that there are 77,000,000 acres of such land, now unproductive, but which with drainage and protection from overflow will have an exceptionally high agricultural value; if divided into 40-acre farms these lands will furnish homes for some 10,000,000 people.

The control of waterways, on which successful navigation depends, is so intimately connected with the prevention of floods and low waters, and works designed for these purposes; with the protection and reclamation of overflow lands, and works designed therefor; with the safeguarding of banks and maintenance of channels, and works employed therein; with the purification and clarification of water-supply, and works designed therefor in conjunction with inter-State commerce; with control and utilization of power developed in connection with works for the improvement of navigation; with the standardizing of methods and facilities and the coordinating of waterway and railway instrumentalities; and throughout the larger area of the country with reclamation by irrigation and drainage, and works designed primarily for these purposes—that local and special questions concerning the control of waterways should be treated as a general question of national extent, while local or special projects should be considered as parts of a comprehensive policy of waterway control in the interests of all the people.

Governmental agencies whose work is related to the use and control of

streams are now in existence in the Federal Departments of War, Interior, Agriculture, and Commerce and Labor; and it is desirable, in order to prevent duplication of work and function and to avoid unnecessary delays in the development of the inland waterways, that means should be provided for co-ordinating all such agencies.

While precise figures are not now obtainable, it is safe to say that the current value of our inland transportation facilities (of which railways form all but a small percentage) exceeds one-eighth of our national wealth; yet these facilities are so far inadequate that production is impaired and the growth of the country is retarded. While trustworthy estimates can not be made without further data, it is reasonable to anticipate that congestion of inter-State commerce can be obviated in large measure by judicious improvement of waterways adapted to barge and boat traffic, at a figure much less than that estimated by competent authorities for so increasing railway facilities as to meet present needs. It is desirable that additional data be obtained by requisite expert investigation.

It is conservative to estimate that judicious improvement of the waterways of the country will confer direct benefits through increased transportation facilities which will exceed the cost, while the collateral benefits will be at least comparable with the gain to commerce. Under a co-ordinated plan, such collateral benefits as the enhanced value of lands reclaimed by irrigation and drainage, the value of water-power developed, the increased values due to the prevention of floods and low waters, and the great benefits of purified and clarified water, will more than balance the cost of the works.

In a comprehensive system of waterway improvement and control designed to meet present and future needs, the practicability of any project will depend not alone on local and general demands of commerce, but measurably on attendant natural and industrial conditions, including nature of banks and bed, suitability of the ground as a foundation for works, volume of water and liability to floods and low stages, configuration of the watershed and its susceptibility to control by judicious agriculture and forestry or by reservoirs and other means, local and general demand for pure water-supply, amount and value of available water-power incident to the works, proximity and cost of structural materials, relations to existing and prospective projects on the same and neighboring waterways, and all other physical and economic factors entering into or tending to counterbalance the cost; and the local surveys or plans for any project should take account of all such natural and industrial conditions and be adapted to the attainment of maximum benefits at the minimum cost.

Existing data concerning the volume, regimen, and other physical features of most streams are meager and imperfect. Since plans for improving and controlling the waterways and utilizing the waters must rest on these facts, it is desirable that means be employed to extend and perfect physical data relating to the navigable and source streams of the country.

The benefits of a comprehensive system of waterway improvement will extend to all the people in the several sections and States of the country; and the means employed should be devised so far as possible to distribute the cost equitably through co-operation between Federal agencies, States, municipalities, communities, corporations and individuals.

In order to improve the inland waterways for navigation, and at the same time co-ordinate the agencies and means of transportation, develop the collateral benefits of waterway improvement, adapt all natural and industrial conditions related with waterways to the attainment of maxi-

mum benefits at the minimum cost, and perfect means for distributing the cost equitably between Federal agencies, States, municipalities, communities, corporations and individuals in a prompt and efficient and economical manner, it is desirable to maintain an administrative agency with large powers for the investigation and elaboration of projects under suitable legislative regulation.

The immediate use of natural resources in the rapid development of the country is often allowed to stand in the way of more beneficent and permanent utilization. This is especially true of all resources connected with running waters, the substantial value of which has not been adequately appreciated. It is clearly practicable, without undue expense or interference with current use, to carry out broad plans for the complete development of the resources of the country, and thus assure to the greatest number of people the greatest good for both the present and the future; while if this is not done, the temporary or partial development of these resources will prevent their full utilization for the general benefit. Steps should be taken without delay to outline and initiate the more pressing projects of conservation, and to apply practically the principle of conservation before it is too late.

Our unsurpassed natural wealth and the eagerness of our people for immediate results, regardless of future needs, have led to a policy of extravagant consumption of national resources, and to an encouragement of monopoly whereby an excessive share of such resources has been diverted to the enrichment of the few, rather than preserved for the equitable benefit of the many. Monopolistic tendencies have appeared (*a*) in the extensive control of mineral fuels on public lands whereby large values, essential to the development of the country, have passed beyond public regulation; (*b*) in the acquisition and needless destruction of forests, whose preservation is a public necessity for stream control, for timber supply, and for other purposes; (*c*) in the acquisition of controlling sites on waterways and the appropriation of valuable waterpowers with their segregation from public use without adequate compensation, whereby indispensable utilities escape public regulation in the interests of the people; (*d*) in the segregation of lands, especially in the semi-arid regions, whereby development is retarded so that the lands remain without benefit to commerce or advantage to the growth of the country; (*e*) in the control of products and of transportation to disturb the normal values and natural channels of trade, thereby imposing undue burdens on producers and consumers; and (*f*) in various interferences with the production and commerce of the country, whereby prosperity is curtailed and progress impeded. While such monopolistic tendencies have been conspicuous in connection with the agencies of transportation, they are now, in many cases, opposing the best utilization of streams by diverting their control from State and Federal jurisdiction in the public interests to personal and corporate means of excessive and burdensome profit. Since transportation is a primary factor in the existence and development of any people, and is increasingly important with the growth of population, it is essential that its means should be regulated in the public interests; and any plans for relieving congestion of transportation in the United States should be so framed as to employ all proper State, Federal and municipal agencies in protecting from monopolistic control, not only the agencies and avenues, but also the materials of inter-State commerce.

The recommendations of the commission, given below, show that its members fully agree in the view that National co-operation with the several States is desirable, both for the fullest development of the subject

and in order to insure equitable co-operation between waterway and railway facilities. That this can best be accomplished by the appointment of a national waterways commission is one of the most important of the recommendations, but all are worthy of attentive consideration. The recommendations of the commission are as follows:

We recommend that hereafter plans for the improvement of navigation in inland waterways, or for any use of these waterways in connection with inter-State commerce, shall take account of the purification of the waters, the development of power, the control of floods, the reclamation of lands by irrigation and drainage, and all other uses of the waters or benefits to be derived from their control.

We recommend that hereafter both local and general benefits to the people shall be fully considered in any such plans for the improvement of navigation in inland waterways, or for any use of these waterways in connection with inter-State commerce; and that wherever practicable Federal agencies shall co-operate with States, municipalities, communities, corporations and individuals with a view to an equitable distribution of costs and benefits.

We recommend that hereafter any plans for the navigation or other use of inland waterways in connection with inter-State commerce shall take full account of transfer facilities and sites, and of the location of tracks, grades, bridges, dams, depots, and other works on navigable and source streams, with a view to equitable co-operation between waterway and railway facilities for the promotion of commerce and the benefit of the people.

We recommend that any plans for improving the inland waterways shall take account of the present and prospective relation of rail lines to such waterways, and shall ascertain so far as may be whether such waterways, when improved, will be effectively used in the face of railway competition; and that the relations between railways and waterways be further examined with the purpose of devising means of rendering the two systems complementary and harmonious and making such fair division of traffic that rates and management may be co-ordinated economically and with benefit to the country.

We recommend the adoption of means for ascertaining regularly all facts related to traffic on the inland waterways, and for publishing the same in a form suitable for general use.

We recommend the adoption of means for ascertaining and rendering available, at such rate as to meet public necessities, all requisite data related to the physical character and general utility of the navigable and source streams of the country.

We recommend that hereafter any plans for the use of inland waterways in connection with inter-State commerce shall regard the streams of the country as an asset of the people, shall take full account of the conservation of all resources connected with running waters, and shall look to the protection of these resources from monopoly and to their administration in the interests of the people.

We recommend that the Congress be asked to make suitable provision for improving the inland waterways of the United States at a rate commensurate with the needs of the people as determined by competent authority; and we suggest that such provision meet these requisites, viz.: Expert framing of a definite policy; certainty of continuity and co-ordination of plan and work; expert initiative in the choice of projects and the succession of works; freedom in selection of projects in accordance with terms of co-operation; and the widest opportunity for applying modern business methods.

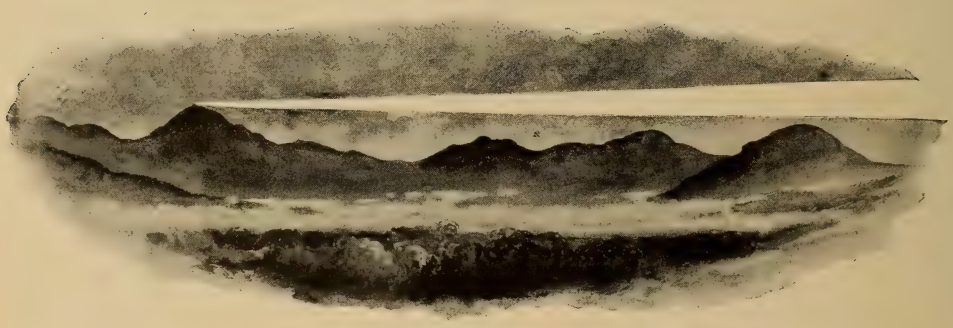
We recommend that the Congress be asked to authorize the co-ordination and proper development of existing public services connected with

waterways; and we suggest that such enactment might provide that the President of the United States be authorized, with the advice and consent of the Senate, to appoint and organize a national waterways commission to bring into co-ordination the Corps of Engineers of the Army, the Bureau of Soils, the Forest Service, the Bureau of Corporations, the Reclamation Service, and other branches of the public service in so far as their work relates to inland waterways, and that he be authorized to make such details and require such duties from these branches of the public service in connection with navigable and source streams as are not inconsistent with law; the said commission to continue the investigation of all questions relating to the development and improvement and utilization of the inland waterways of the country and the conservation of its natural resources related thereto, and to consider and co-ordinate therewith all matters of irrigation, swamp and overflow land reclamation, clarification and purification of streams, prevention of soil-waste, utilization of water-power, preservation and extension of forests, regulation of flow and control of floods, transfer facilities and sites and the regulation and contion thereof, and the relations between waterways and railways; and that the commission be empowered to frame and recommend plans for developing the waterways and utilizing the waters, and as authorized by Congress to carry out the same, through established agencies when such are available, in co-operation with States, municipalities, communities, corporations, and individuals, in such manner as to secure an equitable distribution of costs and benefits.

Referring more *in extenso* to the question of the merging of local projects and uses of the inland waters in a comprehensive plan designed for the benefit of the entire country, the commission calls attention to some of the general features of the problem.

The task is large, and is affected by projects for improving waterways and opening canals for navigation and other purposes, which are now advocated by numerous associations of citizens in various parts of the United States. These projects are so connected with geographic conditions and with natural resources as to fall into four great systems, viz.: (1) The Atlantic-interior system, comprising the Atlantic watershed, the Mississippi Valley, the Gulf slope and the Great Lakes with their watershed; (2) the Columbia-Puget system, comprising the territory west of the Rocky Mountains and north of the forty-second parallel of latitude; (3) the California system, comprising the valley of California; and (4) the Colorado system, comprising the watershed of Rio Colorado and the Great Basin of the interior. In the Atlantic-interior system there are projects for a deep waterway from Gulf of Mexico to the Great Lakes; a deep and continuous Atlantic inner passage from New England to Florida; improving or canalizing Mississippi, Missouri and Ohio rivers with their leading tributaries and connecting the Mississippi waters with the Great Lakes by canals; improving the navigable rivers flowing into Gulf of Mexico and Atlantic Ocean; connecting the Mississippi with the Rio Grande and with the waters of Florida by inner passages; and connecting the Atlantic coast with the Great Lakes by canals. In the Columbia-Puget system there are projects for improving the lower Columbia and the Williamette and Snake for navigation and power development; opening the channels and lakes of the upper Columbia and some of its tributaries to navigation, and constructing feeder and connecting canals; and also for extending reclamation through irrigation, drainage, and the control of floods. In the California system there are projects for improving and canalizing Sacramento, San Joaquin and Feather rivers and the coastwise bays in such manner as to open California Valley

to inter-State and foreign commerce, and also for clarifying the streams, preventing floods and developing power; and in the Colorado system there are projects chiefly thus far for irrigation, but prospectively for navigation and power. In all these systems—indeed in every State and Territory—the respective obligations of the State and Federal Governments to the people and the relations of vested interests are of such complexity as to demand prolonged consideration, not only by the commission, but by State and Federal officials; and it would seem premature to outline a general plan necessarily affecting so many and so varied obligations and interests pending the conference on conservation, at which it may be anticipated that the interest of all the people will be represented.



A PORTABLE FLASH STEAM GENERATOR

By H. W. Bolsover

IN the issue of this magazine for September of last year, there was given some account of the principle and practical application of the flash system to the generation of steam for motive power, with illustrations of actual machines. To these are here added data and information of one of the latest developments in this department of steam engineering, in the form of a 60 horse-power, three-cylinder, vertical, single-acting engine and petroleum-fired flash generator.

This set has been specially designed to meet the requirements of a light and portable steam plant, and owing to the employment of the highly superheated steam which is obtained from the flash steam generator, it is able to show an economy of steam consumption which compares very favourably with that of a large triple-expansion condensing engine. The engine is specially constructed to allow of highly superheated steam being used. The cylinders are $4\frac{1}{2}$ inches bore by 5 inches stroke. The total temperature of steam employed is approximately 950 degrees F. With this degree of superheat, double-acting engines having slide valves with packed glands are out of the question. For this reason single-acting engines with cam-operated poppet valves have been

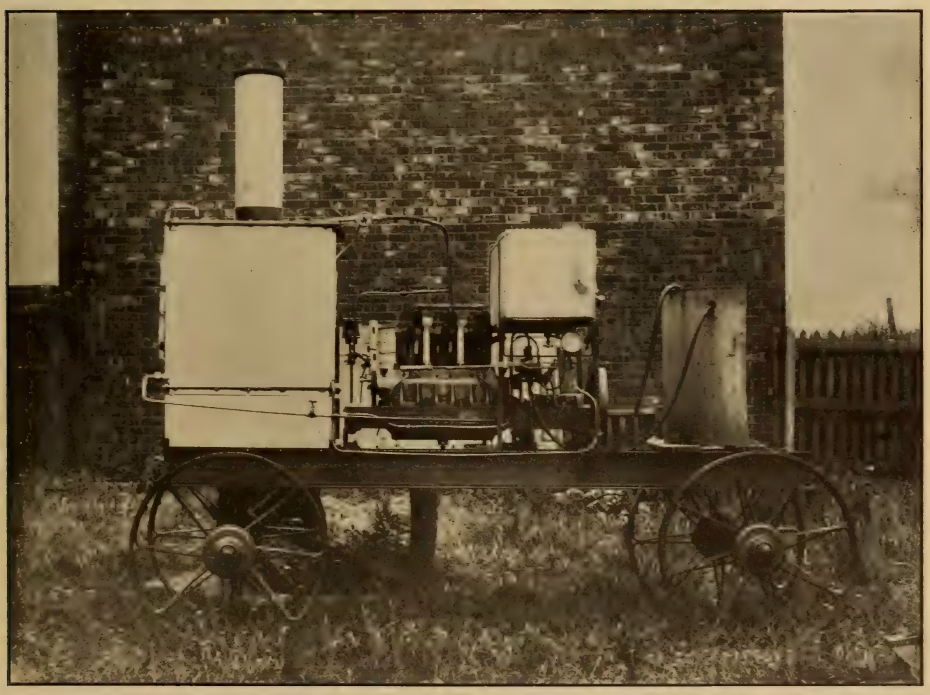


FIG. 1.—PORTABLE FLASH STEAM POWER PLANT.

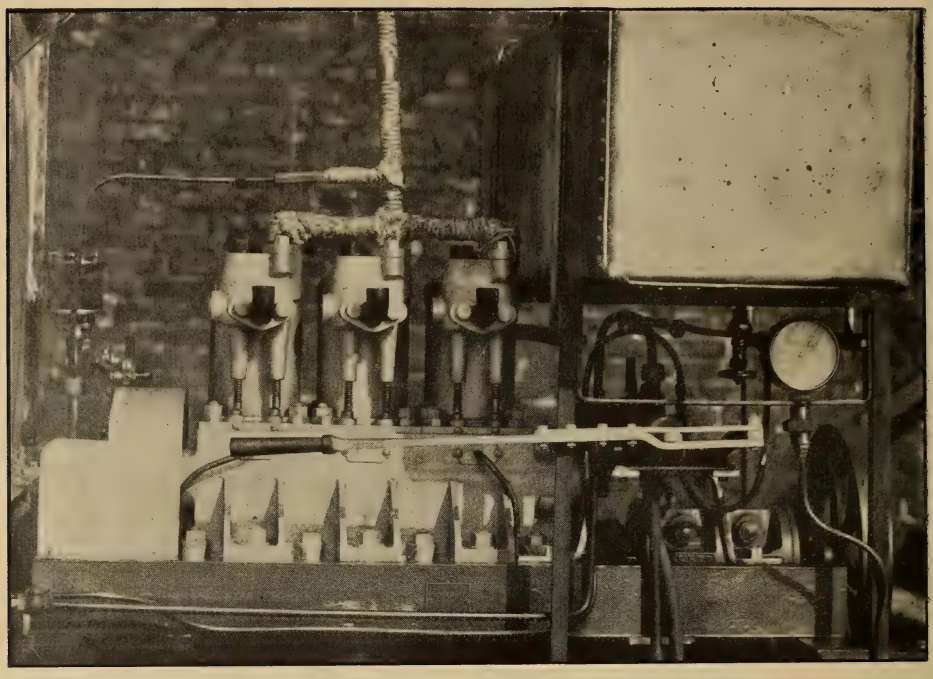


FIG. 2.—VERTICAL ENGINE FOR USE WITH FLASH GENERATOR.

adopted. The cranks, connecting-rods and the cam motion are enclosed in an oil-tight case, and these parts are lubricated on the splash system. The cams operating the valves are so shaped that varying degrees of cut-off can be given to the valves. The range of cut-off is from one-fifth to seven-eighths of the stroke, and it is effected by sliding the cam shaft. This type of valve gear has the advantage of giving practically full opening and closing of both steam and exhaust valves instantaneously.

The lubrication of the cylinders is effected by means of a positive pump-feed lubricator, which forces oil into the main steam pipe in exact proportion to the engine speed.

The flash steam generator is of rectangular shape, and is composed of grids of cold-drawn, weldless steel tubing. These are stacked together and the necessary joints made by fusion-welding by means of the oxy-acetylene blow-pipe. The four bottom sections nearest the fire are coupled to the rest of the grids by steel union joints brought outside the casing. These are, therefore, readily removable for renewal. The burners are likewise so constructed that they can be slid out of the boiler casing for cleaning and inspection. The whole generator is tested to 2,500 pounds per square inch hydraulic pressure.

The working pressure is 400 pounds per square inch. The system of feeding the steam generator and burner is by means of a special automatic pump driven off the engines. This supplies oil to the burners and water to the generator in the exact proportions required to give a predetermined steam pressure. Fig. 1 shows the general arrangement of the plant, and Fig. 2 is a closer view, showing the engines; the fuel is carried in the overhead tank seen in Fig. 1.

The complete weight of the engine and generator for 60 brake-horse-power is 1,568 pounds, and the apparatus is manufactured by Messrs. Bolsover Bros., Ltd., of Eaglescliffe, Durham.

IS COPPER ESSENTIAL TO THE ELECTRICAL INDUSTRY?

By H. M. Hobart

WE have grown accustomed to consider copper as an indispensable constituent of electrical installations and apparatus; in this we are, in a large measure, wrong, and are unreasoningly accepting the precedent set by established practice.

Copper has always entered largely into the construction of electrical apparatus, and has been employed in even larger quantities in electrical transmission systems, both overhead and underground.

It is not necessary to emphasize the immense advantage which would accrue to the electrical industry were it independent of the manipulations of copper speculators. In the following table are given for the last twelve months the current prices of copper and of other metals.

TABLE 1

Monthly Average Prices of Metals in Pounds Sterling Per Ton

Month	Aluminium	Copper	Iron (Pig)	Steel (Magnetite)	Lead
November, 1906	200	101	2.95	58	19.8
December, 1906	200	105	3.1	58	20
January, 1907	200	107	3.0	58	20
February, 1907	200	107.5	2.8	58	20
March, 1907	200	106	2.7	58	20
April, 1907	200	99	2.8	58	20.5
May, 1907	200	102	3.05	58	20.5
June, 1907	200	97	2.9	58	21.5
July, 1907	200	95	2.85	58	22
August, 1907	175	80	2.85	58	20.2
September, 1907	150	69	2.75	58	21
October, 1907	150	59.5	2.75	58	21.5
Maximum price during twelve months....	200	107.5	3.1	58	22
Minimum price during twelve months....	150	59.5	2.7	58	19.8
Ratio (maximum price—minimum price)..	1.33	1.81	1.15	1.0	1.11

From the table it is evident that the fluctuations in the price of copper are far more violent than in the prices of the other metals. When copper rises in price it is well nigh impossible for the electrical manufacturer to obtain for his apparatus a price at all commensurate with the increased cost, due to the higher price of copper. Consequently, he must be content with a smaller profit. When copper falls in price, there is at present a strong tendency, due to overproduction and competition, to unduly lower the price of electrical machinery, but inasmuch as it is much more easy to lower than to raise prices, each cycle of rise and fall in the price of copper leaves the electrical manufacturer with a smaller margin of profit. Obviously were it practicable during periods when the price of copper is temporarily high, to turn to other metals, the electrical manufacturer would be more exempt from these, to him, so disastrous consequences. So large an amount of capital is tied up in drawings, patterns and tools, that it is utterly impracticable for a manufacturer to quickly change his designs, otherwise at certain of the periods indicated in the above table, where the price of copper has been abnormally high, it would have been more economical to substitute other metals for copper. Quite aside from the question of the capital investment in tools and patterns, the lack of initiative on the part of the manufacturer and his disinclination to enter comparatively untrodden paths, con-

strain him to continue employing copper in large quantities, notwithstanding its artificially high price, and notwithstanding the availability of other, sometimes even more satisfactory materials for various of the purposes for which he continues to employ copper.

Let us first turn our attention to dynamo electric machinery, and consider in how far the manufacturer could dispense with copper. It is not sufficiently realized what enormous quantities of copper are annually employed in commutators of dynamo electric machinery. Now that the advocates of the alternating-current motor have changed their attitude from one of scornful contempt for commutators to the other extreme of considering a disproportionately large commutator as one of its most desirable components, the annual consumption of copper for use in commutator construction bids fair to increase even more rapidly than heretofore. The use of copper for commutator segments is founded upon an absolute misapprehension of the phenomena involved. Practically all the losses in a commutator occur at the surface, and are phenomena of friction between the brushes and the commutator, of electrical resistance losses at the contacts between the brushes and the commutator, and of losses due to sparking. There has never been, to the author's knowledge, the remotest approach to a conclusive demonstration that copper has, in these respects, any distinct advantage over iron or steel. Copper has been almost exclusively used for commutator segments ever since the early days of the electrical industry, but the hundreds of thousands of tons of copper which have been required for this purpose have, in his opinion, been no more serviceable than an equal weight of iron or steel. Certainly a considerable amount of experimental work will be necessary before we can, with entire success, employ iron and steel for commutator segments, but the cost of such experimental work will be absolutely negligible in comparison with the savings which will be effected in the course of a single year. When this matter is brought up, one is usually met with the retort that the proposal has been tried and has been found wanting. It has been tried in a half-hearted manner, and even in these cases has not always been found wanting, but has, on the contrary, in certain cases coming within the author's experience, been prematurely discarded, owing to one or other of the numerous reasons which are invariably opposed to radical projects by those engineers who are utterly unqualified to themselves undertake them, and who devote their energies to thwarting the work of their more enterprising colleagues.

For the windings of the field magnets of continuous-current machines with salient poles, aluminium has advantages. Aluminium field spools have been vigorously exploited during the last year or two, and there is certainly a legitimate, though possibly limited, field for them. The legitimate range of application of aluminium field spools increases with the ratio of the price of copper to that of aluminium, and it is quite conceivable that at almost any time this ratio will rise to a value justifying the fairly wide use of aluminium field spools. The customary proposition is to depend for the insulation between adjacent turns, upon the oxide formed on the surface of the aluminium wire. Were one to reinforce this oxide with a layer of insulating enamel, the case for aluminium field spools would be much stronger, for, as is now well known, considerable insulation strength may be provided by an almost negligible thickness of suitable and properly applied enamel.

For windings embedded in core slots, the field for aluminium is more restricted, and here, it would appear, that even at a comparatively high price, copper will continue to be the most economical material to employ.

Let us, however, suppose for a moment that it were made a condition that copper should not be employed, even for armature windings. Would electrical manufacturers in such an event be so very greatly handicapped? This question can be emphatically answered in the negative. Designs intelligently prepared with a view to this condition, would, it is true, be widely different from designs where copper is available for the windings, but they would not necessarily be greatly inferior, nor much more expensive. In a general way it may be said that one would simply employ a much larger flux, and a relatively much smaller number of turns. It is well known that these proportions are generally the most favourable to a good design, and that they have only been abandoned for so-called "strong" armatures under the stress of competition, for machines with strong armatures may, in a general way, be said to be the cheaper.

There is no doubt, in the author's opinion, that for the greater range of rated outputs, speeds and voltages, the total works cost of dynamo electric machinery would be increased by more than 20 per cent. by the imposition of the condition that no copper should be employed in its construction. There are, of course, certain types where copper should preferably be employed, even were it to rise in price considerably above this year's maximum. Amongst these may be mentioned turbo-alternators, where good regulation is dependent upon very high field strengths, and where mechanical conditions, notably the permissible centrifugal forces, constrain the designer from increasing the size of the machine, quite aside from any question of increased cost attendant upon increase in size. In transformer design the substitution of aluminium for copper would also be considerable of a handicap, but would be by no means so disastrous in its consequences as might at first sight be supposed.

Turning our attention from dynamo electric machinery to transmission lines, let us first consider overhead construction. Here we find hundreds of miles of line already in operation in which aluminium conductors are employed. Whereas, however, it is precisely in such cases that aluminium has been strongly advocated. There is no doubt that this is by no means one of the most favorable fields for aluminium. Thus let us consider the stresses to which the line towers are subjected. Although the vertical component of the total force acting on the towers is considerably reduced, owing to the lower dead weight of conductors when aluminium is used, the horizontal component of this total force is considerably increased, since a larger surface is offered by the conductors to the wind, and the moment of this horizontal force about the base of the tower is further increased, the line of action of this force being higher above the ground, since a higher tower is necessary.

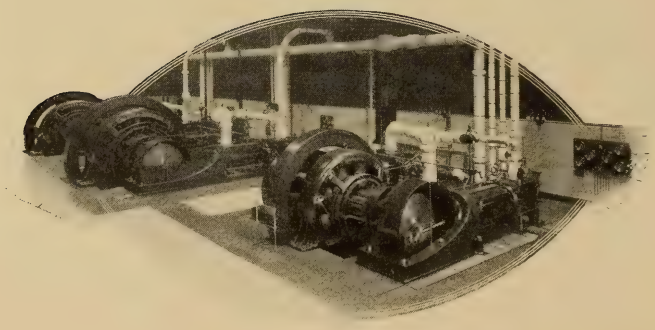
The increased height of tower is due to the larger sag required for an aluminium wire of equal conductivity. The necessary strength and the cost of the tower depend for far more on the value of this bending moment than on the dead weight to be supported, consequently a tower for an aluminium line will certainly cost no less than one for a copper line of equal carrying capacity. Nevertheless the disadvantage of aluminium in such work will, at the most, be comparatively trifling, and there is ample evidence that entire reliance can now be placed upon the use of bare stranded aluminium cables for overhead transmissions.

For underground cables, on the contrary, engineers have been too hasty in concluding that aluminium could be of no service. It is true that the increased section is, from certain standpoints, a handicap, but with the constant tendency to the use of increased voltages for underground cables, the insulation thicknesses are becoming very consider-

able, and the external diameter of an underground cable for transmitting any considerable amount of energy at other than low voltages is, only in very small measure, dependent upon the diameter of the contained conductor. Another, and most important, factor must be considered in this connection. The thickness of the insulation for a given disruptive strength may be less the greater the radius of curvature of the conductor to be insulated. Consequently the greater diameter of an aluminium conductor of a given carrying capacity permits of a lesser depth of insulation for a given disruptive strength than for the case of the equivalent copper conductor. Thus, all told, correctly designed aluminium cables will, for a great range of work, be almost inappreciably larger than the equivalent copper cable, and they will be somewhat lighter and cheaper.

The above instances by no means exhaust the subject. Copper is at present used far more widely than is by any means justified by true economy, for terminals, switches, switchboards, bus-bars, binding posts, and for various other purposes that will readily occur to the engineer.

The author's view is that were it not for the tremendous cost entailed by the change in practice, *i. e.*, the cost entailed in outlay for new tools, designs and patterns, the electrical industry would suffer but a very inappreciable handicap were it to restrict its consumption of copper to one-half, or less, of the average for the last year or two. This could not but have a wholesome effect on the copper market—from the electrical manufacturers' standpoint.



MODERN HYDRAULIC MACHINERY

By Carl Wigtel

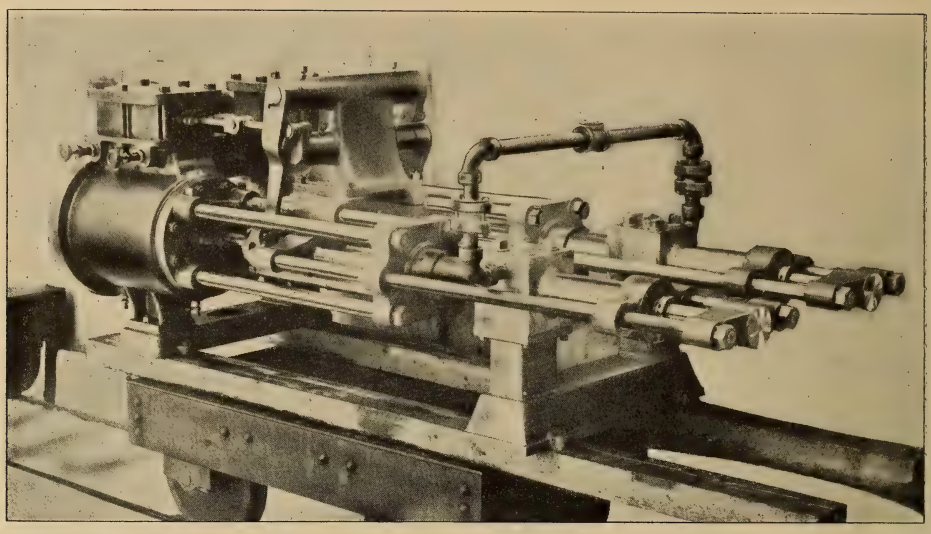
DURING recent times the development of hydraulic machinery has been such that there is hardly any department of engineering work into which it has not shown its value, and in all departments of work, hydraulic appliances are to be found in active service. Formerly the hydraulic press was understood to be a slow-moving, cumbersome machine, capable of exerting a great pressure, but consuming a long time in doing so. Now, however, all this is changed, and by the use of powerful pumps, accumulators for storing the power, large mains for distributing the fluid pressure and suitable operating valves for control, the hydraulic press of today has had added to its power the important element of speed, so that several strokes per minute may readily be attained. A modern hydraulic plant is equipped with high and low-pressure pumps and accumulators, so that the power consumed in the operation of the machinery is greatly reduced, while for special purposes hydraulic intensifiers are also often used to great advantage.

The present article will deal mainly with the production and distribution of the pressure fluid, this branch including the pumps, accumulators and pressure-generating machinery, and in another paper some account will be given of the machinery in which this fluid pressure is utilized in the various departments of mechanical industry. This will be followed hereafter by another paper devoted to hydraulic presses, special hydraulic machines and operating valves of hand or semi-automatic control.

The fluid pressure utilized in hydraulic machinery is produced in the first place by pumps, the force subsequently being transformed in the cylinders of the presses or intensifiers or stored in accumulators. Such pumps are operated either by hand or by power, being driven by steam, turbine or electric motors. The efficiency of power-driven pumps depends, to a great extent, upon the efficiency of the motor. Direct-acting steam pumps are also used to a great extent in connection with hydraulic machinery, but they are not very economical in their consumption of steam.

For hydraulic jacks and for testing apparatus, hand pumps are generally used, and with such pumps the proportion between the plunger and lever is often so great that one man can develop a pressure of more than 10,000 pounds per square inch. Such a pressure, exerted upon a press having a plunger 16 inches in diameter, would give a total force of 2,000,000 pounds, or 1,000 tons. By such methods a man of average weight and strength can thus raise 1,000 tons, but owing to the great difference between the area of the plungers of the pump and the press, the progress of movement of the press is necessarily very slow. Thus, if we assume the effective push of a man upon the pump handle as 100 pounds, the travel of the plunger of the 1,000-ton press would be only 1/20,000 part of the movement of the pump plunger. This slowness of motion is overcome by the use of power-driven pumps, so that the press plunger can be lifted rapidly, while at the same time exerting a great pressure.

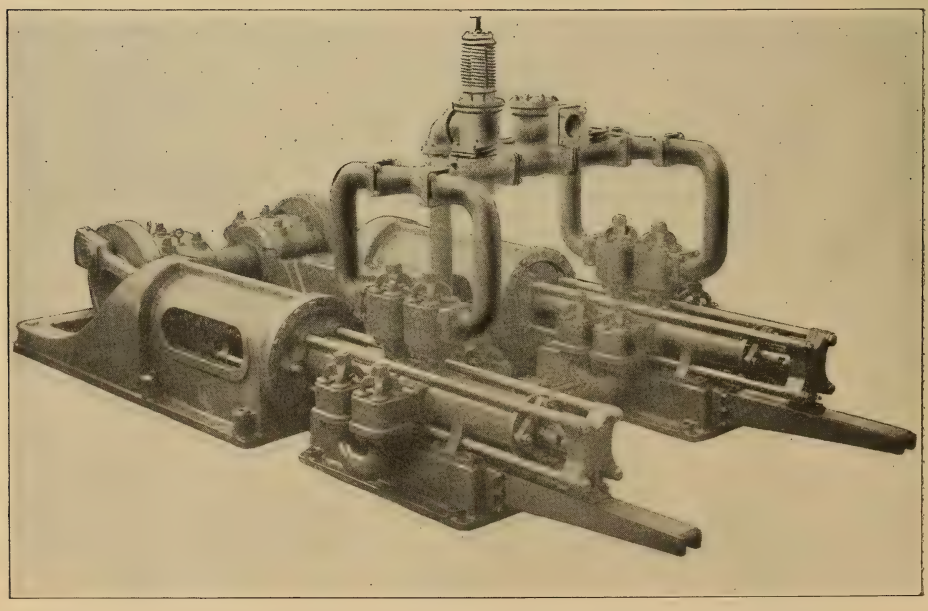
A variety of hydraulic pumps are



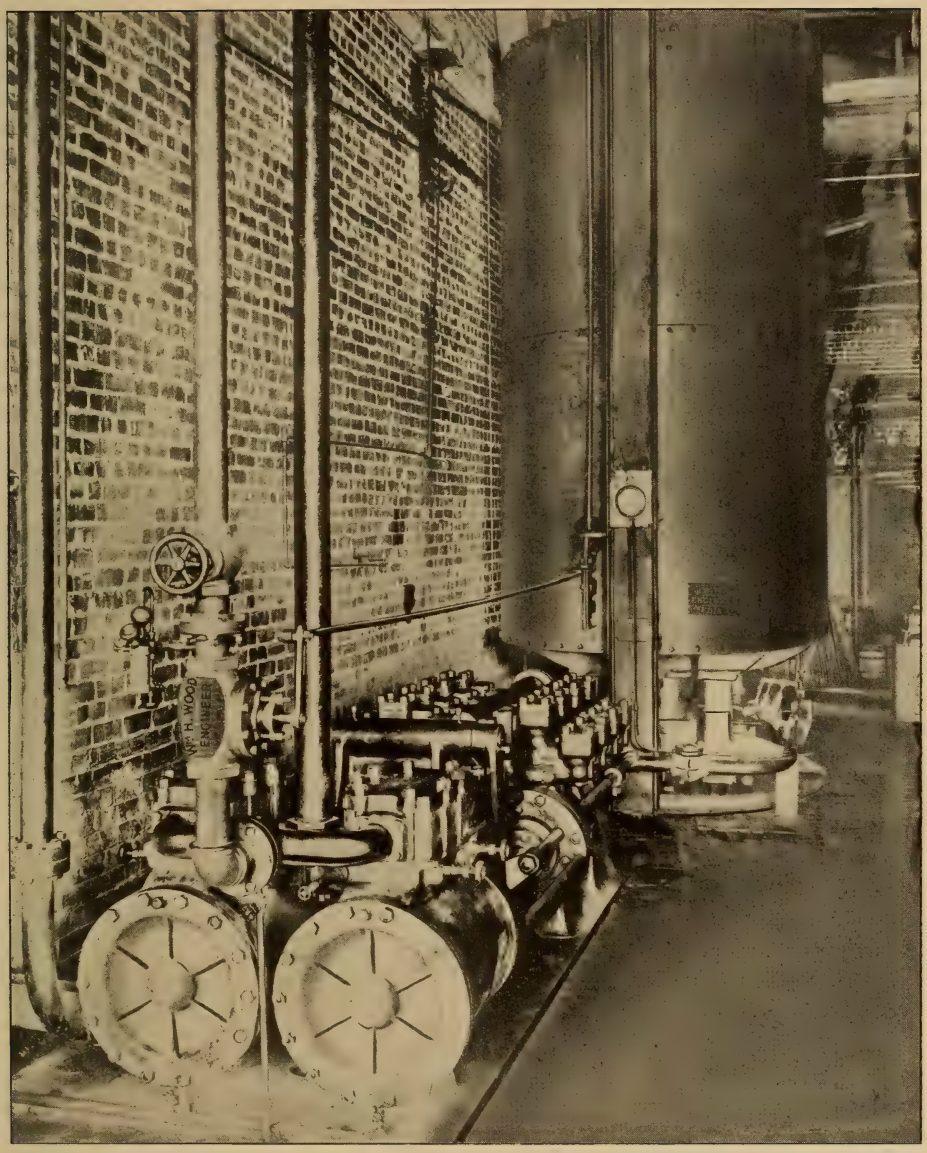
DUPLEX DIRECT-ACTING STEAM PUMP

shown in the accompanying illustrations, these including a duplex direct-acting steam pump, arranged to develop a working pressure of 5,000 pounds per square inch; also a belt-driven pump with four plungers, capable of delivering 40 gallons of water per minute against a pressure of 5,000 pounds per square inch, and requiring 135 H. P. for its operation under these conditions. Similar pumps are made for operation by electric motors, while another pump shown is intended to be geared to a steam engine and to deliver 800 gallons per minute against a pressure of 1,000 pounds per square inch.

In some cases a single pump is ar-



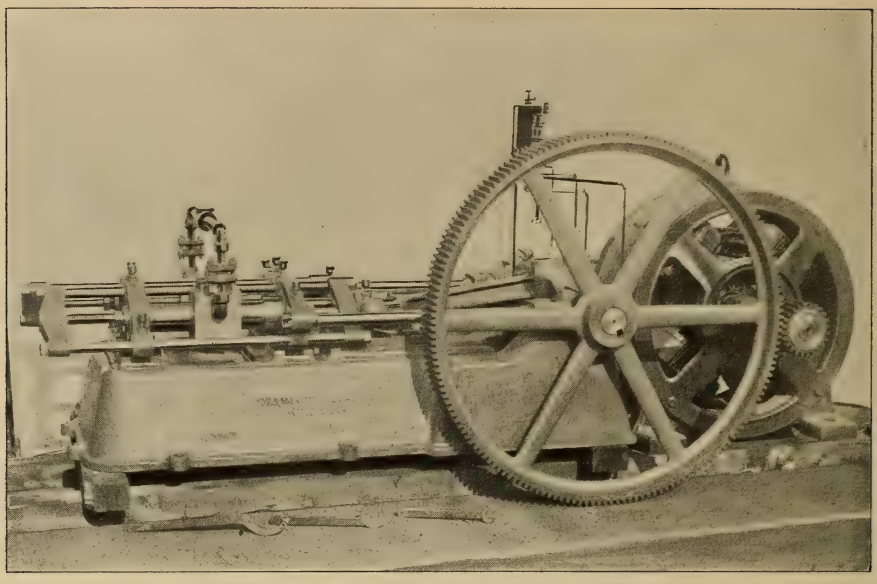
FOUR-PLUNGER HIGH AND LOW PRESSURE BELT-DRIVEN PUMP



HYDRAULIC STEAM PRESSURE PUMPS AND ACCUMULATOR, AT FROST MANUFACTURING CO., GALESBURG, ILL. BUILT BY W. H. WOOD, MEDIA, PA.

ranged for two pressures, and such a pump is shown in one of the illustrations. In this case two of the four plungers deliver to a high-pressure accumulator and the other two plungers are connected to a low-pressure accumulator.

The fluid pressures used in hydraulic machinery are selected with reference to the nature of the work to be performed and the style of machines in which they are to be used. Pressures between 100 pounds and 500 pounds per square inch are considered as low pressures, while for large plants, pressures ranging from 500 to 2,500 pounds per square inch are generally employed. For some styles of hydraulic presses the accumulator pressures reach 3,500

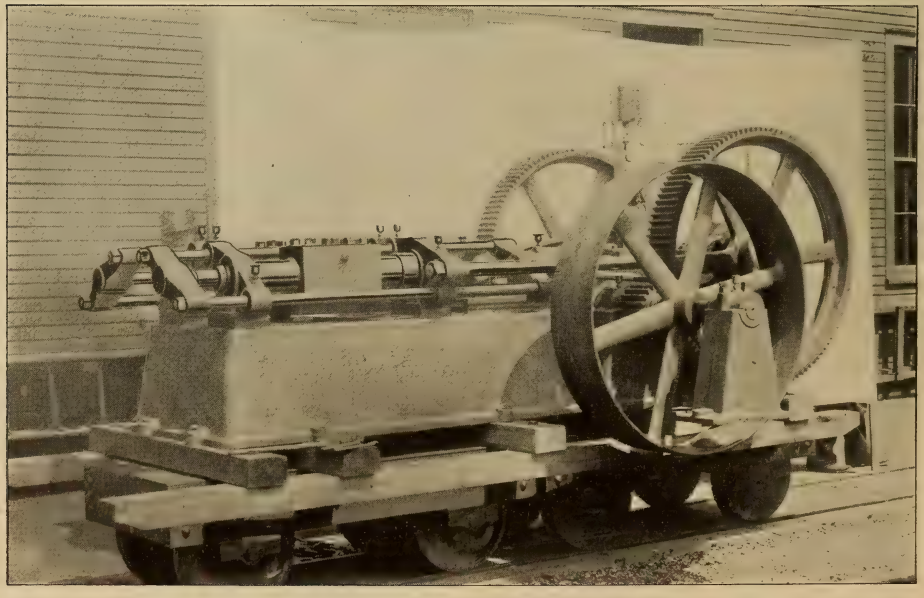


FOUR-PLUNGER PUMP GEARED TO ELECTRIC MOTOR

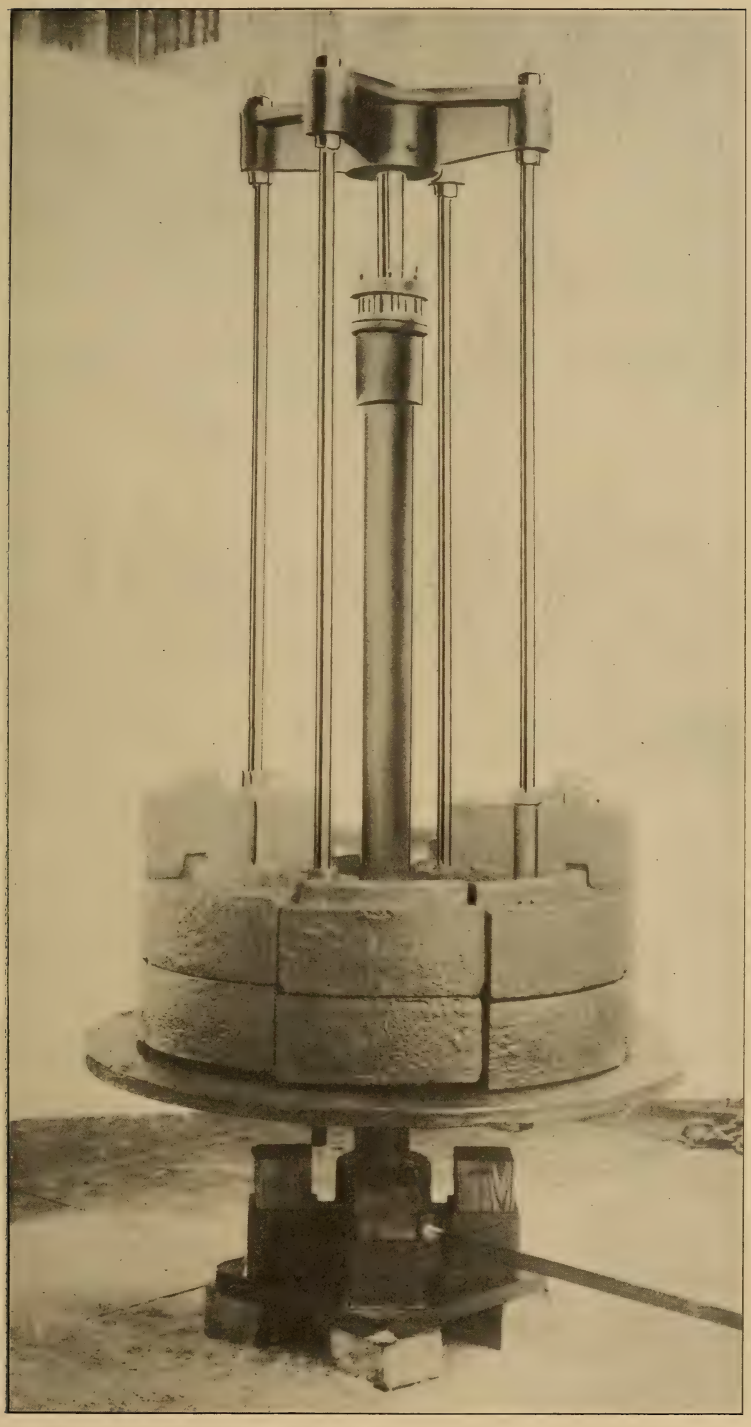
pounds per square inch, and occasionally the pressure attains 5,000 pounds.

The pump does not often deliver its pressure directly to the press, the accumulator being interposed between the pump and the operating machine.

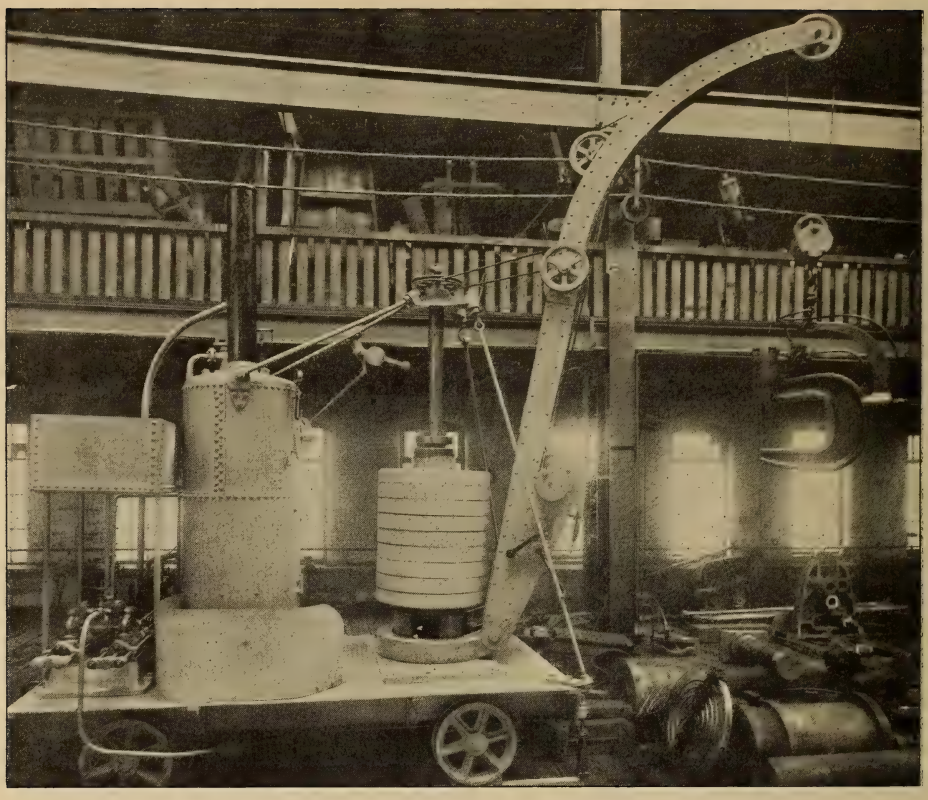
The accumulator serves a double function, the principal purpose being to store up the hydraulic power, while incidentally its motion is caused to control the starting and stopping of the pumps by which it is served. After being once started, a pump and accumulator equipment is generally designed to continue in action auto-



FOUR-PLUNGER BELT-DRIVEN PUMP, FOR 5,000 POUNDS PRESSURE PER SQUARE INCH, WATSON-STILLMAN CO.



WEIGHTED HYDRAULIC ACCUMULATOR, WATSON-STILLMAN CO



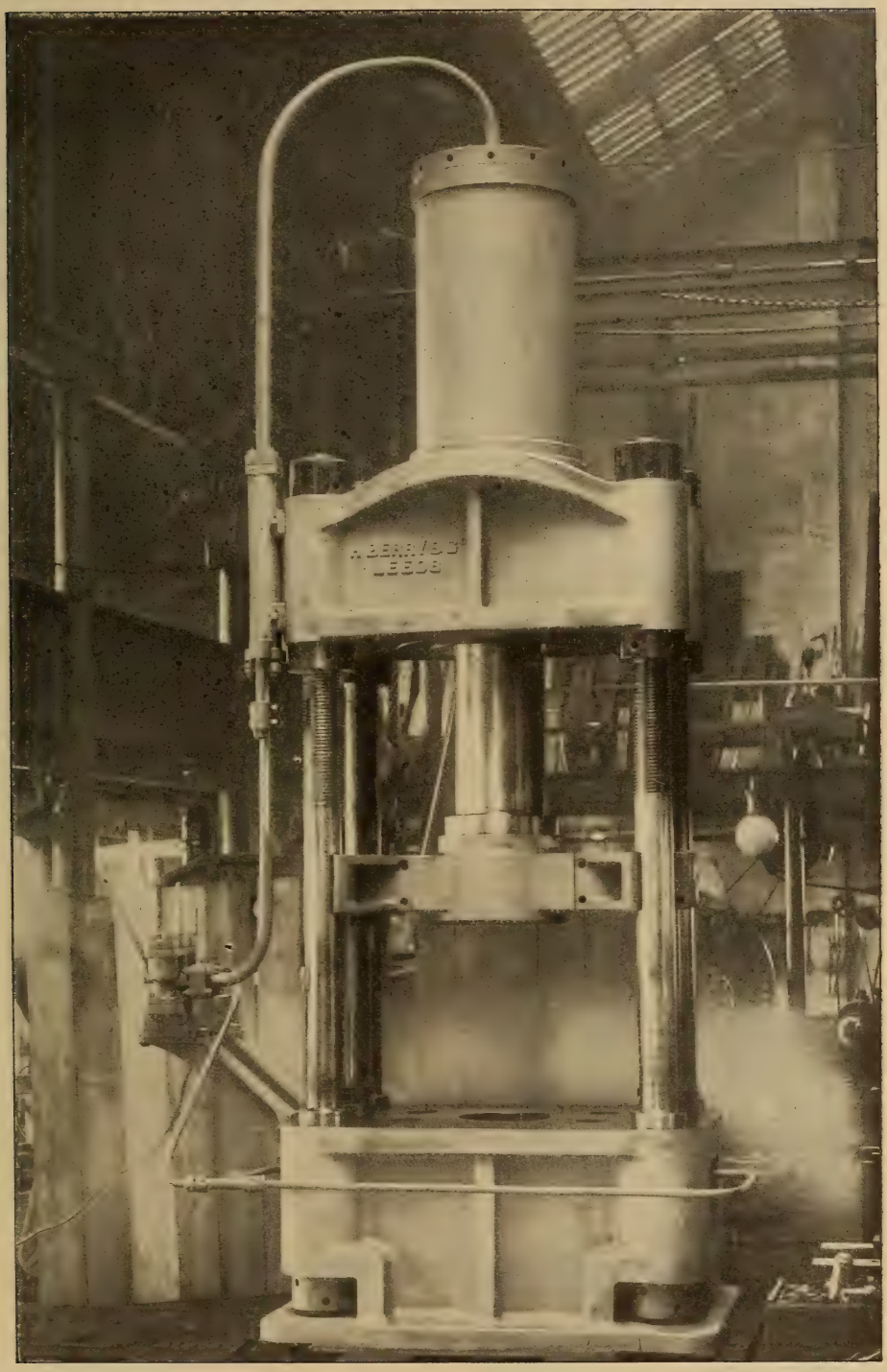
COMPLETE PORTABLE HYDRALIC RIVETING PLANT, HENRY BERRY & CO., LEEDS, ENGLAND

matically, regulating itself without further attention.

The ordinary hydraulic accumulator is a simple device, consisting of a hydraulic cylinder and plunger, similar to a hydraulic press. The difference between a press and an accumulator is, that the plunger of the latter, instead of carrying a platen, is loaded with weights equal to the total hydraulic pressure due to the pump pressure. Several such accumulators are shown in the illustrations. The total amount of weight required for an accumulator is readily computed from the relative plunger areas and the pump pressure. Thus, if the working hydraulic pressure is 1,500 pounds per square inch, and the area of the ram of the accumulator is 50 square inches, the total weight required would amount to $50 \times 1{,}500 = 75{,}000$ pounds.

In certain lines of manufacture it is often necessary to vary the accumulator pressure, and this is simply effected by an arrangement shown in one of the illustrations. The variation in accumulator pressure is effected by a simple arrangement by which one or more weights can be left on the ground when the accumulator ascends. This change is effected simply by moving the pins in the suspension rods from the bottom weight to one higher up. Most of the illustrations show accumulators of the weighted-plunger type, but it is evident that the plunger may be stationary and the weights attached to a moving cylinder, and this form is sometimes used in practice. When the plunger is of small diameter and the stroke is long, the weighted plunger type is generally preferred.

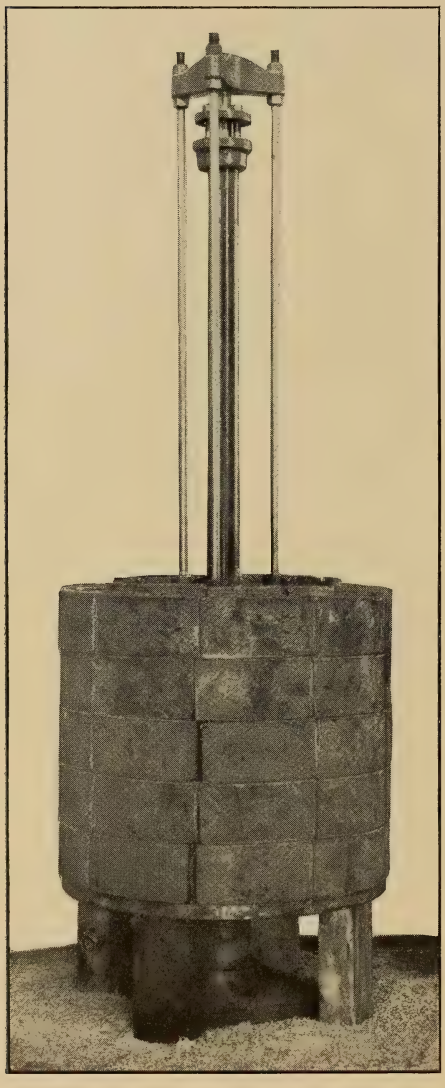
When a weighted accumulator is allowed to descend rapidly, great shocks and jarring effects are often



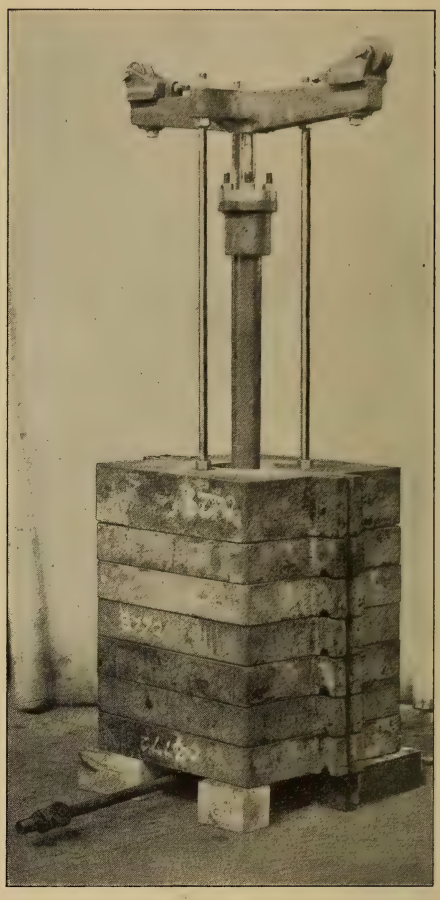
HYDRAULIC SHELL FORGING PRESS, HENRY BERRY & CO., LEEDS, ENGLAND

produced in the machines and pipe connections of the system. This shock, due to the momentum of the falling weight, may be partially overcome by the use of spring-weighted alleviators, connected to the pressure mains at convenient points. Such a hydraulic alleviator is shown in one of the illustrations.

In order to avoid the shocks which occur with the weighted accumulator the hydro-pneumatic accumulator has been designed. In this apparatus the

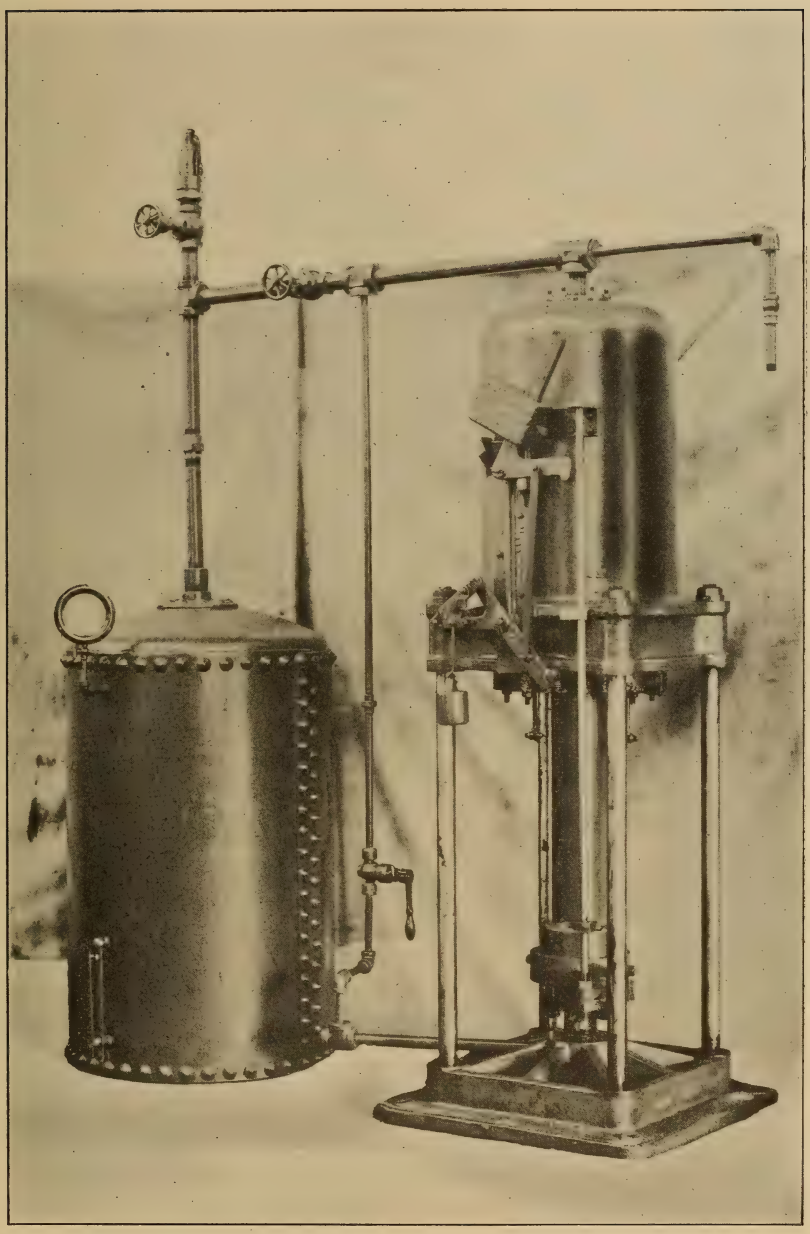


WEIGHTED HYDRAULIC ACCUMULATOR



VARIABLE-PRESSURE HYDRAULIC ACCUMULATOR

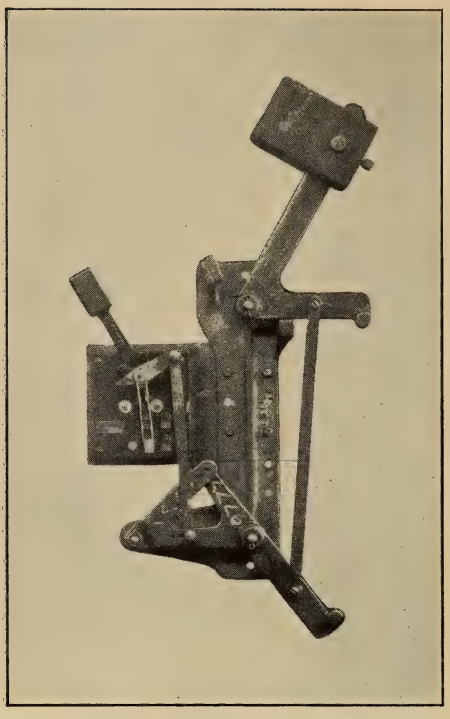
accumulator proper consists of a hydraulic plunger and its cylinder, connected to a large piston which works in an air cylinder. The air cylinder is in direct communication with a large air reservoir, so that the expansive force of the compressed air takes the place of the weights in the ordinary accumulator, the air pressure on the large piston opposing the hydraulic pressure on the smaller plunger. When the accumulator rises, the air is compressed, and when the accumulator descends the air expands. The air reservoir is made of such a size that the variations in pressure do not exceed 5 per cent. of the working pressure; the air pressures in this style of accumulator generally ranges from 150 to



HYDRO-PNEUMATIC ACCUMULATOR, THE WATSON-STILLMAN CO., NEW YORK

250 pounds per square inch, the hydraulic pressure depending upon the ratio between the areas of the air piston and the hydraulic plunger.

A small air compressor is used in connection with the hydro-pneumatic accumulator, but after the air is once stored in the reservoir the compressor is required only at long intervals, to renew the air which may have escaped by leakage. The great advantage of this style of accumulator is the absence of inertia shocks, owing to the absence of heavy weights. It also has the great advantage that the hydraulic pressure

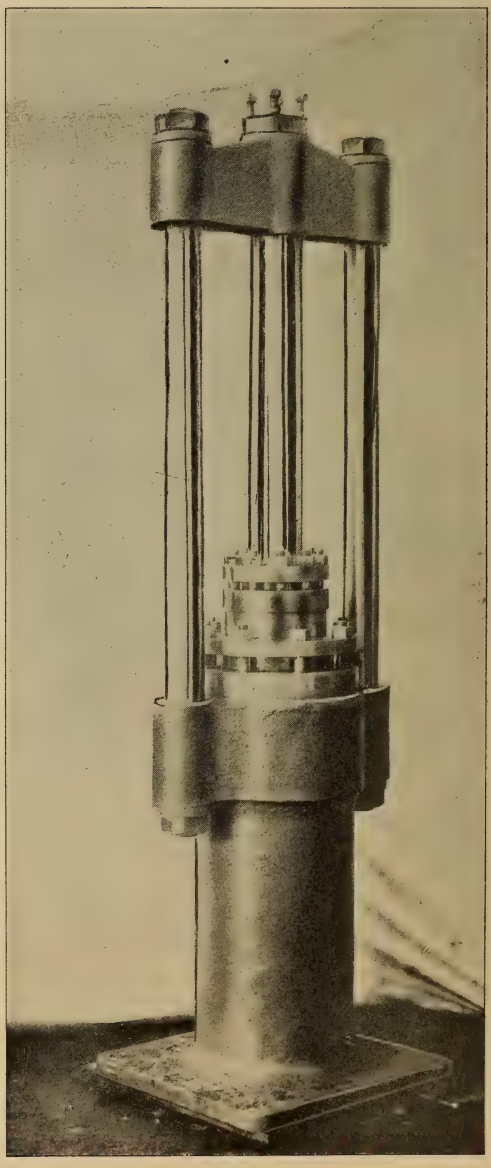


PUMP GOVERNOR, CONTROLLED BY ACCUMULATOR

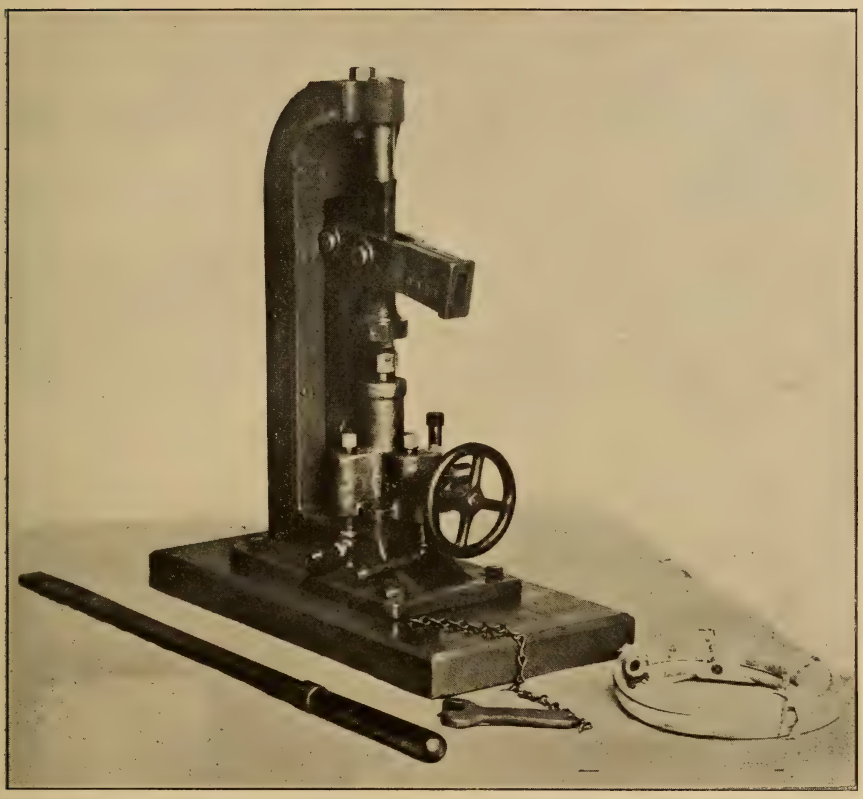
can be varied simply by blowing out some air when it is desired to reduce the pressure, or by increasing the air pressure when a higher hydraulic pressure is required. The hydro-pneumatic accumulator is also capable of use in places where the heavy weighted accumulator would be out of the question, as in the upper floors of tall buildings in large cities.

With but a slight modification the hydro-pneumatic accumulator can be used for high and low-pressure systems. In this case the low-pressure pump delivers to the air reservoir, against a pressure of 150 to 250 pounds per square inch, and a special form of float governor is provided to prevent the water from the low-pressure pump from rising above a certain level in the reservoir. When the water level falls a few inches the pump is automatically started again by the same governor. A similar governor is arranged to control the high-pressure pumps.

Another form of governor for controlling the action of a hydraulic pump is worked by the movement of the accumulator, the governor stopping the pump when the accumulator is up and starting it again when the plunger has descended a short distance. With direct-acting steam pumps the governor is generally arranged to act in connection with a



HYDRAULIC INTENSIFIER, WATSON-STILLMAN CO.



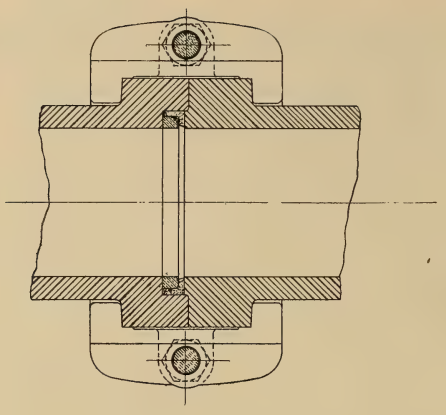
HAND PUMP FOR HYDRAULIC PRESSURE

chronometer valve, which admits or shuts off the steam supply. In some of the four-plunger pumps shown in the illustrations, the regulation is effected by the governor lifting the suction valves of the pumps, thus causing the water to return to the pump cylinders when the action is to be stopped. In the case of pumps driven by electric motors, the automatic self-starter is sometimes arranged to regulate the action by controlling the electric current.

A pump driven by belt or by electric motor may also be controlled by the use of a by-pass valve. With this arrangement the pump is allowed to run continuously, while the accumulator governor opens or shuts a by-pass valve. A check valve is always provided between the by-pass valve and the accumulator in order to prevent the latter from falling down when the by-pass valve is opened.

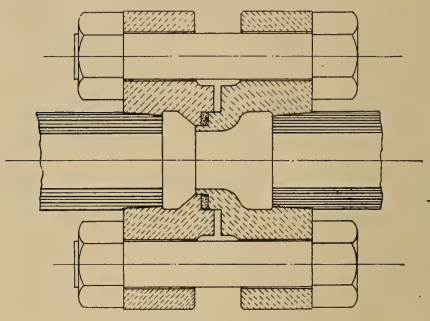
In addition to the regulating devices referred to above, weighted accumulators are sometimes arranged with safety escape valves, the function of which is to prevent the accumulator from being forced out of its cylinder in case the governing mechanism should fail to work. An automatic checking valve is sometimes used in connection with the weighted accumulator to prevent it from falling in case of some accident to the pipe mains.

In order to keep a large hydraulic plant in good working order it is of the utmost importance to have effective pipe connections. Leaky connections cause a great loss in power, besides causing delays and involving much expense by reason of frequent shut-downs. As has already been said, the working pressures in large hydraulic plants often range between 600 and 2,500 pounds per square inch.



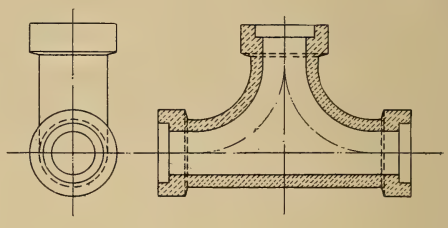
HYDRAULIC CLAMP UNION

When we consider that in some cases modern hydraulic machinery requiring high speeds involve the use of mains as large as 6 to 8 inches in diameter, the importance of providing reliable fittings and pipe joints will be understood. In the accompanying drawings some of the accepted types of such connections are shown. One of these is a hydraulic clamp union for connecting two pipes together. The collars are welded to the pipes, and the packing is made of cup leather, held in place by a packing ring. The clamps over the collars are held together by two bolts, the whole arrangement forming a union which is absolutely reliable for pipes from 2 to 8 inches in diameter and even larger, and for pressures up to 4,000 or 5,000 pounds per square inch. A tee fitting of similar style is also shown, as well as a reliable form



FLANGE UNION JOINT

of two-bolt flange union for pipes of 2 inches in diameter and less, for pressures up to 5,000 pounds per square inch. Fittings of this kind have been found very satisfactory for



HYDRAULIC TEE FITTING

oil-pressures, such as are used in connection with pumps and accumulators for the step bearings of vertical steam turbines.

(To be Continued.)

Current Topics

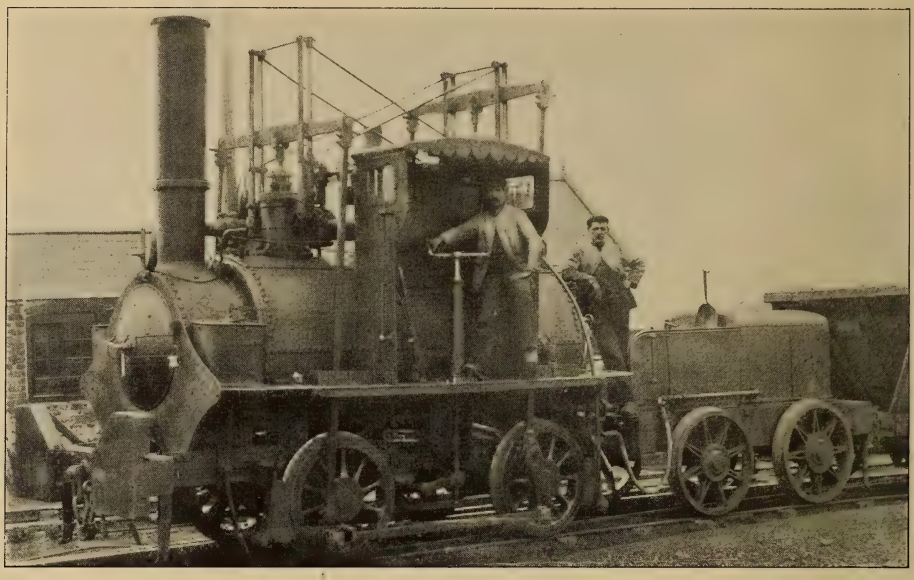
AN important example of the manner in which the development of one department of engineering is dependent upon another is seen in the effect which the reduction of weight of motors has had upon their applications. The early steam engines operated at low pressures and with slow speeds, and hence the size and weight were very great for the power developed. The engines of the *Powhatan*, one of the early steamships of the United States Navy, weighed 508 tons, including all the machinery, and as they developed only 1,172 horse-power, the weight was nearly 1,000 pounds per horse-power. As pressures and speeds increased, the weight per horse-power was reduced, and in some of the higher-powered torpedo boats it has been reduced to nearly 50 pounds per horse-power.

When Daimler undertook to improve the internal-combustion engine so that it could be employed to propel motor vehicles, he realized that the essential thing was to increase the rotative speed, since by this means the power could be increased without material increase in weight. He, therefore, abandoned the flame ignition, then used at the Deutz Works in the Otto engine, and used the hot tube, afterwards substituting for this the electric spark, which had been used in the early Lenoir engines. The result was the modern automobile, since it was only the motor of light weight which was lacking.

The further development of the combustion motor, as regards weight, has been the result of persistent effort directed toward the perfection of details, including the use of materials of the highest grade and the closest attention to the disposition of material in the lines of the stresses, with the elimination of all unnecessary weight. This has resulted in the production of motors which bring the solution of the problem of mechanical flight within measurable approach.

The electric motor, with primary battery, used by Renard in his important experiments with dirigible balloons, weighed something more than 40 pounds per horse-power, and hence the power which he could carry in that manner was very limited. The earlier engines used by M. Santos-Dumont in his experiments with dirigibles were only about one-fourth of this weight, and in response to the demand for still lighter machines, the weight of gasoline motors has been brought down to 2 kilogrammes, and even to 1.5 kilogrammes, or a little more than 3 pounds per horse-power.

This last result has been attained by M. Esnault-Pelterie, who has worked upon the idea that, by the use of a number of cylinders so arranged as to render the turning



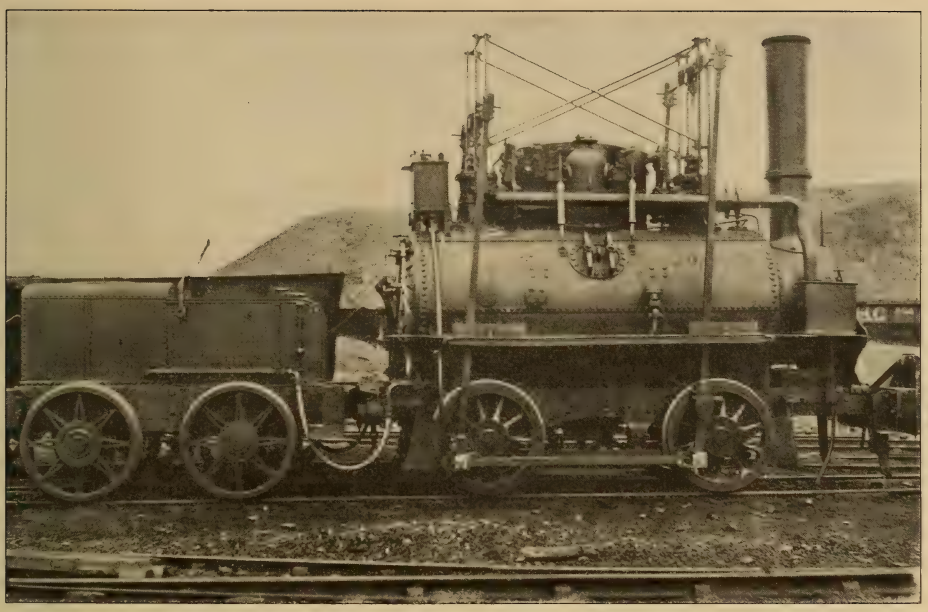
THE OLDEST WORKING LOCOMOTIVE IN THE WORLD, 1822

effect upon the shaft as uniform as possible, the shocks which the members of the machine have to resist may be minimized, and the cross section and weight correspondingly diminished. A seven-cylinder motor of this type, developing 35 actual horse-power, weighs 52 kilogrammes, ready for operation, including carbureter, and with the propeller and its shaft completing the propelling machinery of a flying machine, the total weight is but 60 kilogrammes, or 1.72 kilogrammes per horse-power, or 3.78 pounds.

With such machines available, the problem of the aeroplane becomes materially simplified, and it is not impossible that the use of sustaining screws may become practicable. It is shown elsewhere in this issue that the gas turbine has already been found applicable for the propulsion of submarine torpedoes, and if we admit that the explosion turbine, dispensing with the cumbersome and inconvenient air compressor, is within the bounds of practicability, we have a still wider opportunity for the application of this type of internal combustion motor.

THE visitor to Newcastle-on-Tyne may observe Stephenson's locomotive engine No. 1, mounted upon its pedestal, as a monument to remind him that he is in the country of the beginnings of steam railways. He would hardly expect to learn that, not very far away, a locomotive of similar design, and of almost the same age, was still steadily at work; but such is the case. Stephenson's No. 3, shown in the accompanying illustrations, built in 1822, or seven years before the Rocket made its triumphal run at Rainhill, is still in good and serviceable condition, and in operation at the Hetton Lyons colliery, of the Hetton Coal Company, Sunderland.

As shown in the photographs, this old locomotive is of Stephenson's earliest type, with vertical cylinders, crossheads and connecting-rods extending down to the outside cranks, and although doubtless but few of the original parts remain, the renovations have been of the same style as the originals, so that the locomotive looks much the same as it did when originally put into service. It



STEPHENSON'S NO. 3, AT HETTON COLLIERY, SUNDERLAND

is undoubtedly the oldest serviceable locomotive in the world.

In Galloway's Treatise on the Steam Engine, in the edition of 1830, these early locomotives of Stephenson are thus referred to:

"These loco-motive engines have been long in use at Killingworth Colliery, near Newcastle, and at Hetton Colliery, on the Wear, so that their advantages and defects have been sufficiently submitted to the test of experiment; and it appears that, notwithstanding the great exertions on the part of the inventor, Mr. Stephenson, to bring them into use on the different rail-roads, now either in construction or in agitation, it has been the opinion of several able engineers that they do not possess those advantages which the inventor had anticipated; indeed, there cannot be a better proof of the doubt entertained regarding their utility than the fact that it has been determined that no loco-motive engines shall be used in the projected rail-road between Newcastle and Carlisle, since, had their advantages been very apparent, the persons living immediately on the spot in which they are used — namely, Newcastle — would have been acquainted therewith."

To-day there stands in that same city of Newcastle a statue to the memory of George Stephenson, while one of these same "loco-motive" engines is set up as a monument to his achievements, and another—the one which is here illustrated—is still steadily at work at the same colliery where it was originally installed eighty-six years ago.

AMONG the articles in the present issue of this magazine, attention may be called to the interesting contribution of Mr. Dickinson upon the career of Robert Fulton during the ten years which he spent in England.

Apart from the general attraction which attaches to the careers of men who have effected great commercial and social revolutions, this article brings out more closely than has before been published the relations between Fulton and the firm of Boulton & Watt, showing the original

drawing which accompanied Fulton's order for the working parts of the engine of the *Clermont,* and casting some interesting light upon the manner in which his time was occupied before he went to France.

By comparing the sketch of the engine parts which Fulton submitted to Boulton & Watt with the drawing which he submitted to the French Government in 1803, shown in our issue for September, 1907, and with the illustrations of the engine of the *Clermont* in the present number, it will be seen to what extent Fulton had already conceived his plans for motive power in navigation. The several articles which have thus appeared in these pages, covering the work of Fitch, Symington and Fulton, enable the subject of the beginnings of steam navigation to be traced back to original documentary testimony, and form a fairly connected record of one of the most important epochs in the history of engineering.

THE question of the stability of clay foundations, especially in connection with underground railways and the surrounding structures, has attracted considerable attention of late, and its importance is evident.

During the recent controversy as to the settlement of St. Paul's Cathedral, it was suggested that the London clay was more or less plastic, and, incidentally, the fear was expressed that the tube railways of London must be exposed to flotation influences, which, under the influence of vibration, might gradually compel the tubes to rise, though, of course, slowly. While it can scarcely be said that the London clay is plastic in its present compressed and drained condition, the problem may at least warrant calculation. Taking a foot-length of tube railway, say 16 feet outside diameter, the displacement of clay will be approximately 200 cubic feet, and this, at 140 pounds per cubic foot, will weigh 28,000 pounds. Assuming the tube segments, including flanges and bolts, to have a mean thickness of 2 inches, one foot-length will weigh 25,500 pounds, so that with the rails and sleepers and several cubic feet of ballast, the tube, if so thick, would practically possess no floating tendency.

With a 12-foot tube the clay displaced weighs about 15,800 pounds, and an average thickness of 1½ inches of tube weighs 14,300 pounds, and very little remains to be made up by rails and ballasting.

With the larger tubes at stations, it is easy to add ample weight at the platforms, if such were needed. There does not, therefore, seem to be very much in the fears expressed, for the tubes have little tendency to move.

Apropos of the settlement of St. Paul's, which has clearly occurred, it is extremely probable that the true cause is generally unsuspected. It has been laid to the boring of the tube railway down Cheapside, but this is extremely improbable, for the amount of gap left is very small, and is too far away to affect the Cathedral, whatever it may have done by Bow Church. Then, again, it has been laid to the drainage of the surface soil, which seems quite an untenable supposition, in face of the fact that there is water in the gravel upon the London clay, and, so far as the clay is concerned, an inch of water upon it will keep it as wet as a foot.

The true cause of the settlement seems far more probably due to the numerous artesian wells in London. At one time the chalk-water level under London was above the river level. Now it is below the level of the London clay. Whereas formerly the upper surface of the chalk-water pressed against the under surface of the clay with a pressure of some 50 pounds to the square inch, now it does not touch; the dry and sandy strata are interposed between the clay and the water. Thus for years now there has been a tendency for the clay to lose its water and shrink,

and it has shrunk and allowed buildings to settle. It has shrunk most under the heavier parts of buildings, as might be expected. With the clay in a dry condition, there is certainly less further likelihood of shrinkage. Like sand, clay, unless confined, is not a first-class material for foundations. When moist, it is possessed of a considerable property of plasticity, and foundations ought to be carried, perhaps, further below what may be termed weather conditions than has been done in the case of the Cathedral.

WHILE we would always deprecate too much reliance being placed upon deductions drawn from tests on individual pieces of machinery, and especially pieces of machinery constructed for academical purposes, nevertheless every respect may be awarded to the third report of the gas engine research committee recently presented to the Institution of Mechanical Engineers by Professor Burstall, of Birmingham.

The tests forming the machinery of the research were made upon a gas engine specially constructed, one excellent feature of the test arrangements being that, when it was desired to vary the degree of compression, this was effected by inserting packing pieces in the connecting-rod end, so that the charged volume of the compression space was simply measured as $0.7854\ d^2t$, where d is the cylinder diameter and t the added thickness of the packing.

The tests showed—and probably this would prove fairly general in application—that for each compression there is a particular mean pressure, which gives the highest economy for that compression, and this mean pressure appears to range between 85 and 95 pounds for all compressions. If the mean pressure became higher, the efficiency began to decline, and this is attributed to the cooling action of the walls, this no doubt being more active as the internal temperature of the cylinder increases. It is, of course, wrong to treat the gas engine as a heat engine pure and simple, for it is by no means that. It is a combination of engine and water heater, and the fact noted above should spur on those who would try at least to remove the water-jacket from the combination chamber. Johnstone has done this with his oil engine, and with success. Thwaite and Booth have long advocated the suppression of combustion at the dead point of the piston, on the ground that at that moment the hot gases are exposed to the full effect of the jacket, that they are not then expanding and producing work, that they are putting the crankpin and shaft bearings under maximum pressure when these are rotating at full velocity, yet transmitting no work, and, therefore, it is better to delay maximum cylinder pressure until the crank has reached a more effective angle. The reporter seems to think that the test engine is of a design of maximum economy, as probably it is. He would secure higher thermal efficiency by raising the ratio of stroke to cylinder diameter—1½ to 1 in the test engine; but as, so he says, this would demand slower rotation, the lower speed might countervail the higher compression economy.

It seems that very high mean pressures of 114 pounds per square inch proved decidedly uneconomical, while the very high pressure of 600 pounds produced were beyond the safety of the engine. The engine was of the scavenger type, as a precaution against premature ignition. All cases of this fault which occurred during the tests were traced to dirt or carbon in the cylinder, and occurred alike with weak or rich gas. Is not this fact a somewhat powerful argument in favour of the more scientific system of supplying gas and air from an outside source—to an advance, in fact, upon the Clerk cycle, so that the gas engine may be double-acting, two-stroke, and of higher mechanical

efficiency than the machines which now appear so very clumsy for a given power? But for its double mean pressure, as compared with a steam engine, the gas engine would seem still more clumsy in its four-stroke, single-acting form.

IT has often been debated who should have charge of an electricity station. Many of the electrical engineers who, in the past, have been put in full control of electric generating works, have been telegraphists, electric bell men, and, indeed, have had even less connection with electricity. But to be an electrician of any sort has been sufficient for the municipal council of some places to hand over great steam-power stations to men with really no engineering experience. The result has been, no doubt, to give a great setback to good steam practice. To-day, however, the electrical man does receive an engineering training, but it is training in electrical engineering and not in steam engineering; and it must be admitted that electricity is quite sufficient for a man to master, without his being expected to acquire a sound knowledge of steam work also. So it is, perhaps, soundest wisdom to say that the man in charge of an electric generating station should be neither a steam nor an electrical engineer. The steam end should be in charge of a steam engineer, and there he should stop, the electrical end of the plant being in charge of an electrician. Had such an arrangement been in operation at the Greenwich station, which has become so prominent of late because of the recent Board of Trade inquiry into the explosion of a thermal storage vessel, it is probable there would have been no explosion. A steam engineer would have laid off the drum for examination as soon as the first leakage in a tension plate made itself manifest. Indeed, probably most steam-boiler experts would have prevented the leakage by inserting longitudinal stays, which might have prevented the cracking of the plate, or would have at least allowed it to crack so badly without rupture as to compel laying off the vessel.

With pressures of 160 pounds, it is unfair to put steam boilers into the charge of electrical men, for it is exposing such men to the consequences, it is depriving steam engineers of their fair share of work, and it means the exposure of workmen and of the public to serious danger. If any man takes on himself the charge of steam boilers who has had no experience in steam boilers, he renders himself more seriously responsible for accident than does the really expert man, for the latter will not take obvious risks of danger, and although he may commit errors of judgment, he has acted on long experience. Now the man of no experience cannot plead error of judgment, for he has not acquired the means of forming any sort of judgment. Devoid of experience, he is wilfully speculating in other men's lives. This the experienced man does not do. He makes an honest endeavour to do the right thing, knowing something of the many ways in which steam boilers do fail. Such a man has earned a right to exercise a judgment, but the man of no experience has no right of judgment, and becomes culpably responsible from the simple fact of having accepted a position for which he is unfitted. Let the two duties be properly divided. The economy of a power station is determined in the boiler and engine house, yet the man in charge knows usually nothing of steam. Can the waste of fuel be marvelled at, or the smoke?

THOSE who were present at the Board of Trade inquiry into the Greenwich boiler explosion must have been struck with the evidence on the plate that failed, and appraised the value of the conflicting evidence in their own minds. Here there is steel plate which fails by

cracking round the root of a flange, and, on one hand, the makers of the plate declare that the ductility of the plate has been inured by impressing into it a close series of depressions by means of the snap of the rivetter used in closing the plates before rivetting. But the boilermakers claim that these slight depressions or indentations would not inure a really ductile plate, and, therefore, the plate was initially of too harsh a quality.

Very little seems to be known about steel even to-day, but it is becoming known that this little is known. It is a moot point whether a steel plate can be boiled—at high pressure at least—and retain its ductility. The mere bathing of a steel plate in acid, or dilute acid, to remove scale, is thought to produce brittleness. Even age itself is supposed to conduce to trouble. There is, in fact, general confession, and yet, at the same time, there is an undercurrent of opinion, that really good steel, as understood by a steel manufacturer, suffers none of these untoward things. It has been much claimed, for example, of late that American broken rails were due to the running of heavier locomotives over the rails, which were too light for the loads. But some observant American steps forward and says that older—much older—British imported rails, which have been down for years and are much lighter than the rails which fail, carry the same heavy loads and do not fail. The inference is that the early British steel rails were better rails than are most new rails, contained probably less phosphorus, and took much more rolling in course of manufacture.

WHAT sort of valves ought to be employed for superheated steam? Since superheat practically destroys oil exposed to its full temperature, and since the admission valves of a steam engine are exposed to the superheat temperature, they must not have rubbing surfaces under load. The ordinary slide valve is well known to be inadmissible, and the Corliss valve appears to find an early limit to its safe running at about 500 degrees F. There seems to be nothing left available but some form of drop valve or mushroom valve, such as is employed for the exhaust valve of the gas engine. Such a valve simply shuts down on a seating ring with no rubbing movement. It comes to rest gently under the control of a dashpot. Such valves are of very ancient use in steam engines. They have been known as Cornish or double-beat valves, or as equilibrium valves, two valves on one spindle, balancing each other as regards steam pressure. As drop valves or stamper valves, they were once common in Lancashire, and now they again come into use for superheated steam. It is claimed for them that they leak little or no steam, for being circular and symmetrical, they do not tend to warp under change of temperature if made from good, even homogeneous material. In the latest valve for superheat, a simple piston drops almost exactly like the drop valve, except that it drops across a port in the shell, and does not need to be brought to rest exactly at a given point, for it may drop swiftly past the cut-off port and then be gently arrested. This permits of easier and more elastic working, and the valve possesses certain other features in its mode of action which seem to fit it for dealing with superheated steam in a satisfactory manner, such as, for example, the fact that when it moves to open it is surrounded with steam that has probably lost its superheat, and so it moves easily, and when it drops to cut off steam, it drops suddenly across the steam before the steam has had time to heat the valve.

FRANCIS H. STILLMAN

A BIOGRAPHICAL SKETCH

IN the early fifties of the last century the old Novelty Works were famous as the principal machine shop of New York, building all kinds of machinery, including marine and stationary engines, sugar machinery and special products. The principal mechanical engineers of the organization were the three Stillman brothers, Thomas B. Stillman being at its head.

The sugar machinery department was in charge of Alfred Stillman, while Paul Stillman, the father of the subject of our sketch, had in his hands the fine work of the shop, including steam gauges, indicators, pyrometers and similar products.

Paul Stillman failed in health and died in 1856, leaving his only child, Francis, who had been born in 1850, and the boy's education began at Mystic Bridge, Conn., where he took the high-school course, and then, having removed to Wisconsin, he entered Milton College.

Various plans for a technical training have been discussed by eminent educators, and one system which has been advocated is that of interpolating a course of shop training between academic courses. This plan was followed by young Stillman, for he took an apprenticeship course in the shop of the Cottrell & Babcock Printing Press Works, at Westerly, R. I., and then entered preparatory classes in the Cooper Union, passing from there to the Sheffield Scientific School of Yale University, from which he was graduated in 1874.

In the meantime the first patent for a hydraulic jack had been taken out by Richard Dudgeon, with whom was associated Mr. E. Lyon, the stepfather of Francis H. Stillman, and in 1880 the firm of E. Lyon & Co. was formed, the members of the firm, besides Mr. Lyon, being T. H. Watson, who had been associated as superintendent with Mr. Lyon during the whole of his manufacturing career, and Francis H. Stillman. Upon the death of Mr. Lyon the firm of Watson & Stillman was formed, and the business of manufacturing hydraulic jacks, presses, and other hydraulic machinery was carried on at 470 Grand street, New York City, until the capacity of the shop was outgrown, and the engine shop of William Munzer, in Forty-third street, was purchased and the business transferred to the new location in 1888. The increasing extent and variety of hydraulic machinery manufactured by the firm gradually made this place too small, and about four years ago the business was incorporated as the Watson-Stillman Company, and the plant moved to Aldene, N. J., on the lines of the Lehigh Valley Railroad, and the Central Railroad of New Jersey, where ample facilities for future growth exist.

Apart from his engineering and business activities, Mr. Stillman has shown himself interested in general affairs. For several years past he has been treasurer of the National Association of Manufacturers, and he was the first president of the National Metal Trades Association, and is heading the formation of the new Machinery Club, in New York. He is a member of the American Society of Mechanical Engineers, and has been chairman of its membership and finance committees. He is also a member of the Society of Naval Architects and Marine Engineers, and of the Engineers Club. Mr. Stillman is a thirty-second degree Mason, a Knight Templar and a Shriner. He is also president of the Bridgeport Motor Company, making a specialty of combustion motors and motor boats.

Manufacturing News

The Loomis-Pettibone Gas-Generating System

ONE of the influences which have acted to retard the general introduction of producer gas for power purposes has been the fact that the ordinary systems involve the use of anthracite coal or coke for fuel. This is due to the fact that the volatile constituents of bituminous coals yield tarry products in the producer, and these, passing with the gas into the engine, interfere with the action of the valves and working parts of the machine.

The system of generating gas invented by Loomis and Pettibone, and controlled and built by the Power & Mining Machinery Company, of Milwaukee, has been devised for the purpose of overcoming this difficulty, and by its use the volatile matter is converted into gas, thus producing from bituminous coal, wood, lignite, and similar fuels a fixed, clean gas, free from all impurities, including tar, and especially suited for use in gas engines.

The principle upon which the Loomis-Pettibone producer gasifies bituminous coal and other fuels containing volatile matter is that of reversing the draught, as compared with the ordinary producer, the air being drawn downward through the bed of incandescent fuel by the action of an exhauster, so that all the gas and tarry matters distilled from the fresh fuel in the upper strata of the fire pass down through the deep fuel bed, the resultant gas being fixed and free from tar. The hot gases from the generator pass through a steam boiler, where a large proportion of their sensible heat is abstracted, the steam thus produced being directed into the fire for decomposition.

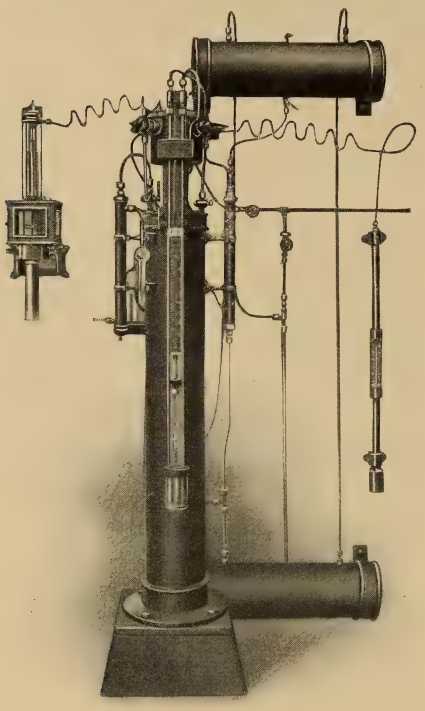
The gas is subsequently washed in a wet scrubber and further cleansed in a dry scrubber, from which it is delivered into the gas holder ready to supply the gas engines.

In view of the enormously extending use of gas engines for the production of power, the gas-producer plant seems destined to find as large a commercial field as has heretofore been open for the steam boiler. When it is considered that by far the greater part of the coal fields of the United States yield bituminous varieties, generally considered unavailable for use in the gas producer, it will be seen how important a question the design of a suitable gas generating system must become.

Practical experience has shown that for units ranging from 250 to 2,000 horse-power excellent results are obtained. For installations under 3,000 horse-power the provision of one spare unit is sufficient to insure continuous action, while for larger plants even this is unnecessary, since the overload capacity of the system is such as to permit of discontinuing one unit at a time for purposes of cleaning or repairs.

The Uehling Gas-Composimeter

IN all industrial operations it is of the greatest importance that full information should be obtained about the work which is being done. This is especially true in the combustion of fuels and the utilization of gases, since small variations often



THE UEHLING GAS-COMPOSIMETER. BUILT IN SINGLE AND MULTIPLE SYSTEMS

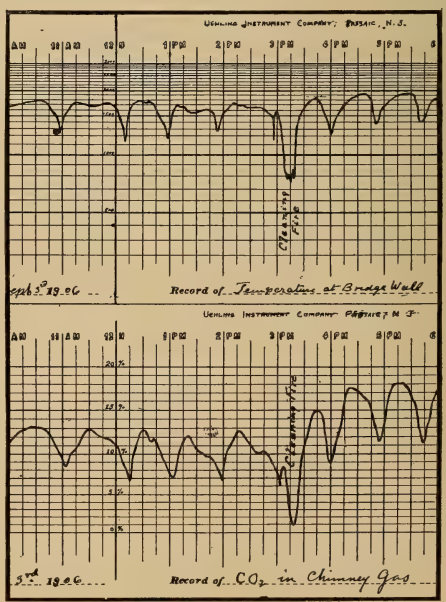
make very large differences in the efficiency obtained.

Formerly an examination of the gases of combustion could be made only in the chemical laboratory, and the time and cost of such an analysis rendered it impracticable in commercial operations, and limited the method to use in connection with important tests.

There is now available, however, an instrument which furnishes a continuous indication of the proportion of carbonic acid in the gases of combustion, and since the proportion is a direct indication of the completeness of the combustion, it is thus possible to keep a continuous watch upon the behaviour of the furnace, or gas producer. This valuable instrument is the Uehling gas-composimeter, made by the Uehling Instrument Company, of Passaic, N. J., and shown in the accompanying illustration.

The principle upon which this instrument is based is that governing the flow of gases through small apertures, combined with the fact that carbonic acid gas may be absorbed by passing it through suitable solutions. By the use of an aspirator the gas to be examined is drawn continuously through a chamber provided with small apertures, and under such conditions two gauges connected to the chamber before and beyond the aperture will show a constant difference in pressure so long as the composition of the gas remains uniform.

If, however, one constituent, such as carbonic acid, be absorbed from the gas in passing through the chamber, the variation in composition will produce corresponding variations in the relative indications of the gauges.


Uehling Instrument Company, Passaic, N. J.
Record of Temperatures at Bridge Wall
Uehling Instrument Company, Passaic, N. J.
Record of CO2 in Chimney Gas

EXAMPLES OF RECORDS MADE BY THE UEHLING COMPOSIMETER

Upon this principle the Uehling composimeter is based, and to it have been added the necessary operative details in such a manner as to render it a continuous automatic recording device of the proportion of carbonic acid existing in any gas drawn through it.

The great value of such a device is apparent. In the boiler room, where the greatest opportunity for gains in fuel economy remain, it gives the fireman as positive a knowledge of the combustion as the steam gauge does of the pressure, or the gauge glass of the water level. If the stoking has been carelessly done, the diagram reveals the fact and the time of its occurrence to the chief. The record of the Uehling composimeter is thus a sure guide to maximum efficiency in the combustion of coal in the boiler furnace.

In like manner the composimeter may be used to show continuously the performance of a gas producer, whether used for fuel or power purposes, and it has thus come to be a most important and invaluable instrument to the engineer of the power plant, the metallurgical works and the innumerable industries based upon the economical combustion of fuel.

These valuable instruments are excellent examples of the improved methods which are coming into use in many departments of industry. Formerly such matters as the regulation of a fire or the determination of a temperature were left to the judgment of experienced operators, and much of the assumed ability of certain classes of mechanics rested upon their supposed capacity to judge such things correctly. To-day such crude assumptions have no place in the best establishments. The behaviour of a fire is as much a matter of record as the indications of the steam pressure or the flow of an electric current. High temperatures are correctly indicated and accurately repeated, and methods which formerly were limited to the laboratory are made a part of the daily operations of the shop.

Christensen Air Brakes for Trolley and Electric Cars

THE Christensen type of air brake, of which there are over 17,000 in daily service, is now manufactured by the Allis-Chalmers Company. The orders for these equipments recently taken indicate no decline in the favour extended to this apparatus. The Consolidated Railway Company, of New Haven, Conn., whose properties are in operation in some thirty odd cities and towns of Southern New England, not long ago placed what was said to be the largest contract for air brakes ever let. It comprised over 280 complete equipments. As a matter of railway history, the first Christensen air brake equipment placed in service in New England was installed in 1898, on a car of the Hartford Street Railway Company, now a part of this system. After nine years of continuous service this identical equipment is still in daily use.

This one installation is a strong recommendation for other traction companies to consider.

The Interborough Rapid Transit Company, of New York City, recently placed an order with the Allis-Chalmers Company for ninety-one 24-foot air compressors and pneumatic governors, the vital parts of air brake equipments, and other important contracts of a similar character have been let by traction companies in all parts of the country.

The Christensen air brakes in regular service are carried on about 350 different electric systems throughout the world. The fact that many of these railways placed their first orders for air brakes years ago, and since then have continued to buy Christensen brakes, shows very conclusively that those equipments in actual operation have given good service and proved the superiority claimed for them.

The simplicity in construction of the Christensen air brake is only one of the features which have brought it into general use on the various traction lines in the United States.

Electrical Appliances on Shipboard

AN essential requirement of every appliance used in naval service is that it shall be under perfect control and management. This applies to the electrical equipment in a special sense, since the very object of installing electrical appliances in naval vessels is to provide methods for prompt and certain control of the motors and the mechanisms which they operate.

In view of these facts, the interesting bulletin, No. 22, just issued by the Cutler-Hammer Company, of Milwaukee, is of especial value, since it is devoted wholly to a description of the various electric-controlling devices which these manufacturers have built in conformance with the specifications of the Bureau of Construction and Repair, the Bureau of Equipment and the Bureau of Steam Engineering of the Navy Department of the United States.

The devices listed and illustrated include starting panels, speed regulating panels, controllers, resistances, circuit breakers, and their details, for both Navy Yard and for shipboard service, the data showing the construction and arrangement and the particular specifications under which they are made.

The Cutler-Hammer Company has expended much time and money in the development of a complete line of controlling devices, conforming in the minutest detail to the stringent specifications of the Navy Department, and this list of apparatus is, therefore, of especial value for manufacturers both of electric motors and of motor-driven machinery who supply this important government department.

Apart from the valuable information contained in Bulletin 22, as regards government work, it may be suggested that devices and methods designed to meet the strict requirements of the Navy Department may be considered as especially well adapted for private installations of the highest class.

Jamestown Exposition Awards

JAMES L. FARMER, secretary of the Jury of Awards, Jamestown Exposition, has notified the General Electric Company that it has been awarded two gold medals and a bronze medal on account of its exhibit at the Exposition.

The classification by which the jury was governed in granting the awards limited them to one in each department, while previous Expositions have allowed separate awards for each class of material exhibited. The General Electric Company's exhibits are grouped in three departments: The Machinery, the Manufactures and Liberal Arts, and Mining Departments.

A collection of motors applied to various machine tools and other devices has been awarded a gold medal. The arc and incandescent lamps and electric cooking applications exhibited in the departments of Manufactures and Liberal Arts are also awarded a gold medal. The company exhibited a special motor designed particularly for use with an Ingersoll-Temple pneumatic rock drill, and this motor, because of its peculiar adaptation to the special service, was awarded a bronze medal. The company was also awarded a silver medal for installation of exhibit.

Columbia University Evening Courses

COLUMBIA UNIVERSITY will offer at night during the year 1907-1908 twenty evening courses specially adapted to the needs of technical and professional workers. This includes work in applied mechanics, architecture, electricity, fine arts, industrial chemistry, mathematics and surveying and structures. The work begins on October 28, and continues for twenty-five weeks. A full description of the courses is contained in the Announcement of Extension Teaching, which may be obtained on application to the University.

PICTURE FRAME MACHINE J A. FAY & EGAN CO., CINCINNATI, O.

Wood-Working Machinery

A MACHINE for cutting two pieces simultaneously to a miter has recently been patented by the J. A. Fay & Egan Company, Cincinnati, Ohio. This is effected in a simple manner by having the two pieces laid across each other in front of the saw at an angle of 45 degrees. The pressure on either side of the saw is equal, therefore the cut is absolutely true.

The frame is a solid cast-iron structure, free from vibration, whose table is mounted on frictionless rollers, and moves easily. A saw mandrel is hung on a swinging frame, and the bearings are adjustable independently. The saw is hollow ground, and the side vibration is eliminated by a guide under the table. The double fence is the important feature of construction on this machine. It is adjustable from a straight angle up to 45 degrees. Angle plates (of wood) are furnished to set in the fence trays when mitering joints for picture frames, to give a deeper set to the frame. The countershaft has 10-inch $\times$ 4½-inch face tight and loose pulleys, and should make 500 revolutions per minute. One 20-inch hollow ground saw is furnished with the machine.

High-Pressure Steam Equipment

THE Walworth Manufacturing Company, of Boston, Mass., issue a neat folder for the consulting engineer and contractor, giving sufficient details on the following high-pressure steam equipments:

"Walmanco," their rivetless flanged-over pipe joint, which is absolutely steam-tight under 250 pounds pressure; heavy valves; fittings; gun metal castings for steam drums, elbows and tees. They are also manufacturers of the genuine Stillson wrench.

Drop-Forging Machinery

CATALOGUE No. 13 of the E. W. Bliss Company, New York, illustrating patent automatic drop hammers of various sizes, with heavy anvils, also trimming presses, straight-sides and tilting, both belt and electrically operated, gives a detailed description (also weight of anvil and weight of drop) of each class of machine above mentioned.

An oil-burning furnace for heating purposes is likewise represented in this pamphlet.

Anthracite Producer Plants

THE advantages of producer gas for industrial operations are generally conceded. Apart from its use as a fuel for use in gas engines it is especially adapted for metallurgical and heating operations, so that in modern practice the direct firing with coal and coke for such purposes is being abandoned.

The Industrial Gas Company, of New York, has issued a bulletin, No. 16, describing the Harvey anthracite gas producer plants, with illustrations, tables and diagrams, containing much valuable information about gas fuel. This includes a discussion of the process of making producer gas, both in the Harvey and the Herrick producers; the arrangement of tuyeres, valves and connections; the use of economizers, scrubbers and regulators, and the general equipment of a plant. To this is appended a very useful treatment of the essential features of burning the gas to advantage, together with the best arrangement of burners, piping and details. These features should be given skilled attention, if thoroughly satisfactory results are to be secured, and in this respect the bulletin is a valuable practical document. Owing to the difference in the nature of the flame and the combustion of producer gas as compared with natural or other high-temperature gaseous fuels, the furnaces in which the former is to be used should be especially designed for the service. This refers both to the furnace itself and to the burners as well, and from the small burner used by the manufacturing jeweler up to the 60-ton open-hearth steel furnace, the skill of the experienced designer should be employed if success is to be attained.

The general discussion given in this bulletin shows that the Industrial Gas Company is fitted, both by the appliances which it controls and the engineers possess, to design and install gas-producer plants for power, for heating, or for metallurgical operations, and in full accordance with the particular requirements of each case.

The Uttlization of Exhaust Steam

THE modern trade catalogue often rises far above the status of a mere list and description of goods offered for sale, and some of the recent publications issued by engineering establishments form most useful treatises upon the subjects with which they deal. An example of such a publication is the pamphlet recently issued by the Harrison Safety Boiler Works, of Philadelphia.

This publication is avowedly prepared to set forth the merits of the Cochrane feed-water heaters and purifiers, but it is, in addition, a most useful discussion of the manner in which exhaust steam may be profitably utilized. This involves an examination of the amount of heat in exhaust steam which can be returned to the boiler with the feed-water; a study of the extent to which impurities in feed-water may be separated by means of heat; a discussion of the methods of using exhaust heaters in cases where the steam is also used for heating and drying purposes, and an examination of the arrangement of feed-water heaters in connection with plants in which the main engine is operated condensing.

Most of these important elements in the operation of a steam power plant are given scant consideration in the text-books and treatises on steam engineering, while in this excellent catalogue the results of a wide practical experience are placed at the disposal of the steam user in a clear and interesting manner.

That this information is given in order to show the advantages of the Cochrane heaters makes the book of practical value, and the care which has been given to the text, illustrations and typography indicate that a similar critical attention is given to the design and construction of the heaters themselves.

Welding With the Oxy-Acetylene Blow-Pipe

THE oxy-acetylene blowpipe, the action of which was fully described in the paper by Mr. Cutler in our September issue, is principally applied to the welding of iron and steel; but copper, brass and bronze may also be welded to advantage by this process. In a recent article in "Metal Industry," some of these methods are discussed as follows:

The principal application of the oxy-acetylene blowpipe is for welding iron and steel, but copper, brass and bronze can often be welded advantageously by this process.

The welding of copper piping by the "Epurite" process instead of brazing is coming into vogue, numerous explosions having been caused by the slow disintegration of the brazing under the influence of the voltaic elements formed by the presence of zinc and copper. The zinc is dissolved gradually by the inorganic acids in water and by the organic acids which obtain in the piping, the brazing being transformed into a copper sponge which is absolutely non-resistant.

In welding copper wires the tensile strength obtained is never higher than two-thirds of the original strength; curiously enough, the wire breaks near the weld, but never at the weld itself. Brass can easily be welded by using borax as a flux.

The acetylene blowpipe can also be used to advantage for repairing bronze and brass castings. Bronze castings, being generally very costly, the repairing of them by this process is of considerable interest. Cracks or flaws are first to be well cleaned, the blowpipe applied, and when the metal begins to melt the interstices are filled by bronze wire held in the flame.

Brass castings can be repaired in the same way.

This useful process is operated by the Industrial Oxygen Company, of New York.

Combustion Motors

BY far the greater portion of the power manufactured at the present time is developed from the combustion of coal, and of this, again, the greatest part is produced from steam engines and boilers. It is estimated that at the present time there is nearly 15,000,000 horse-power developed in the United States, of which more than 10,000,000 horse-power is produced by the burning of coal, about 100,000,000 tons being consumed in the operation.

About 300,000 horse-power, it is estimated, is derived from gas engines, or, as they are better termed, internal-combustion engines, and yet there is no doubt whatever that the internal-combustion engine, burning the gaseous fuel directly in the power cylinder, requires but one-half as much coal per horse-power as the steam engine.

There is at the present time a rapidly growing interest in the development of the combustion engine, and it is probable that in many power plants to be erected in the near future the steam boiler and engine will be replaced by the gas producer and combustion engine. This is the more probable since the structural and operative difficulties encountered in the early attempts to make large gas engines have been practically overcome, and gas engines in units as large as 3,000 horse-power are successfully built and operated. Apart from the fact that the gas engine uses the heat twice as efficiently as the steam engine in the conversion of the latent energy of the fuel into useful work, it has also the still greater advantage of offering the possibility of utilizing fuels of low grade unsuited for the boiler furnace.

Thus there are numerous coals containing such a large proportion of ash that they cannot be burned to advantage under a steam boiler, and yet are well adapted to the manufacture of fuel gas in the gas producer, and thus well adapted for power generation.—"The Forum."

Storage Batteries and Electric Railways

THE value of the storage battery for equalizing the load upon the engines and dynamos operating electric railways is well known and generally accepted. With the introduction of alternating currents for railway service there have arisen a number of problems which have to be met as they occur, and records of these questions are of much practical value.

In Bulletin No. 107, issued by the Electric Storage Battery Company, of Philadelphia, there is given a very interesting account of the manner in which the chloride accumulator has been applied on the Spokane & Inland Railway, Spokane, Wash.

This case was peculiar in that the supply consisted of 4,000-volt,3-phase, 60-cycle alternating current, while the road was to be operated on 2,200-volt, single-phase, 25-cycle current, thus involving the use of frequency changers, as well as of voltage and phase transformers. In order to meet these requirements, a special piece of apparatus was designed by Mr. J. B. Ingersoll, the general manager of the company, in connection with the Electric Storage Battery Company. This, in brief, consisted of an induction motor operated by the supply current, a single-phase generator to deliver the required power to the load, and a direct-current machine to act either as a generator or a motor, these three machines being direct connected and mounted on a common bed-plate. The direct-current machine is connected to a battery of chloride accumulators in connection with a carbon regulator and regulating booster, so that the battery is charged from, or discharges into, the direct-current machine, according to the fluctuations of the load. The details of the apparatus are described in the bulletin, and the effectiveness of its performance is shown by a diagram. The practical effect of the apparatus is to cause all but a fractional part of the fluctuating load to be cared for by the battery through the special transformer sets, of which there are four of 1,000 H. P. each, leaving a practically constant load on the supply line. The battery used in this installation consists of 275 cells of Type R-33, manufactured by the Electric Storage Battery Company, each cell consisting of sixteen positive plates of the standard Manchester type and seventeen negative plates of the box type, in wood tanks lined with sheet lead.

Slip-Drum Electric Winches

EVERYONE who has used the passenger ferry-boats plying across the rivers about New York and other maritime cities is familiar with the geared winches, operated by large hand wheels, for hauling in and making fast the boat to the slip.

Similar winches have been used for handling the large and heavy floats of the car ferries, but they are hardly powerful enough for such work, and even when double geared the work is labourious and difficult.

The Lidgerwood Manufacturing Company, New York, has designed a special slip-drum electric winch for this service, which has many advantages. In the first place, electric power is substituted for human muscles, this giving much greater power, besides enabling the control of both winches to be in the hands of one operator, placed in a tower where he can observe the float and its surroundings. In the second place, the winches are provided with slipping frictions set so that a full stretching strain can be put upon the hawsers, beyond which the drums will slip.

These winches have been designed by the Lidgerwood Company especially to meet the requirements of the great railroad ferries about New York, and embody the principle developed by Mr. Spencer Miller for maintaining a constant tension on the cableways of the Lidgerwood system, so successfully used for coaling ships at sea.

Crankshaft Lathes

THE development of the gas engine and the gasoline motor has brought with it corresponding developments and improvements in machine tools, to meet the constructive requirements demanded. Among the special features of many types of combustion motors the multiplication of cylinders is noticeable, this being partly due to the fact that the power impulses occur less frequently than in the steam engine.

Multiplication of cylinders means multiplication of cranks, and hence the necessity for convenient and effective tools for machinery multiple-throw crankshafts. Among these the Tindel-Albrecht crankshaft lathe has made an enviable name for itself, this useful tool being built by the Tindel-Morris Company, of Eddystone, Pa.

The old method of turning the various portions of a multiple-throw crankshaft was to have driving disks on each end of the shaft, with centres corresponding to the axial lines of the different parts.

For large, stiff shafts this method has been employed with success, but it has always been felt to be open for improvement. In the Tindel-Albrecht lathe the shaft is not only supported at both ends, but driven at both ends. Furthermore, it is also supported and driven at the very point where the cutting is being done, this being effected by means of a movable middle drive, adjustable for each crank-pin and intermediate bearing on the shaft. By the use of adjustable counterweights, the work is completely balanced, and thus a uniform and steady motion is secured, free from tendencies to sag or spring.

The drive at both ends and at the middle of the shaft is effected by means of pinions on a driving shaft at the back of the machine, these pinions gearing into the driving gears attached to the shaft to be turned. This insures uniformity of speed and eliminates torsion strains, rendering it possible to turn any number of crank-pins in strict alignment upon the same shaft. The tool slide and the steady rest are arranged especially for the nature of the work to be done, and the machine is a notable example of good design and construction.

These lathes are made for work of various sizes, ranging from 12-inch swing and 42-inch length between centres to 32-inch swing and 120-inch length, special sizes also being made to order.

Electric Locomotives for Passenger Service

THE New York, New Haven & Hartford Railroad is now running its thirty-five Westinghouse electric locomotives with local trains between the Grand Central Station, New York, and Stamford. The success of the operations involved has exceeded the expectations of the officials of the railway company and of the manufacturers, and it is understood that a considerable addition to the locomotive equipment is under negotiation.

Each locomotive was intended to haul only five-car local trains, but it frequently happens that trains of as many as eight cars are handled with ease by a single unit.

The interpole motors for railway equipments, manufactured by the Westinghouse Electric & Manufacturing Company, are particularly designed to meet the most severe requirements of modern high-speed service and overloads during rush hours and holidays.

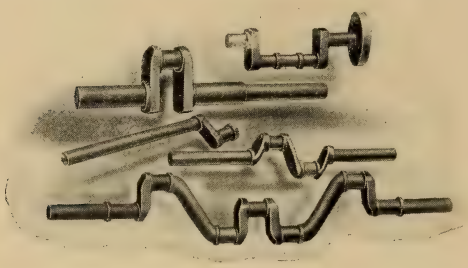
The automatic brake equipments for electric railway trains of three or four cars are arranged for gradual release, quick service and high-cylinder pressure in emergency application.

The prime mover for up-to-date electrical railways is either the steam turbine or the internal-combustion engine. Complete installations of both classes are furnished by the Westinghouse Machine Company in units to meet all requirements.

Multiple Crankshaft Forgings

MODERN tendencies in automobile construction are turning toward multiple cylinders. Multiple cylinders involve multiple-throw crankshafts, and the severe service demanded requires that these shafts shall be forged in the best possible manner from material of the highest grade.

The Wyman & Gordon Company, of Worcester, Mass., already well and favourably known as manufacturers of high-class drop forgings, have given especial attention to this matter of the production of multiple-throw crankshafts, and are making some remarkably complete ex-



amples, viz., four, five and six-throw, with flanges up to 16 inches diameter, the crank set at any angle. These forgings will weigh from 20 pounds to 400 pounds, and are made with such accuracy that it is only necessary to remove the minimum of metal, either by grinding or turning, to give a complete and finished shaft. These shafts, concerning which we shall have more to say in a forthcoming article, with illustrations, are forged complete, without welds, ready for the lathe or grinding machine, and represent the latest development of high-class forgings in standard or special alloy steels. It is by such attention to the production of detailed parts that the modern combustion motor has attained the combination of strength, lightness, and reliability which characterizes the best modern machines, a completeness to which manufacturers like Messrs. Wyman & Gordon have contributed an important part.

First Principles of Drying

A SUBSTANCE becomes dry by the evaporation of its inherent moisture into the surrounding space. If this space be confined it soon becomes saturated and the process stops. Hence, constant change is necessary in order that the moisture given off may be continually carried away.

In practice, air movement is therefore absolutely essential to the process of drying. Hence the necessity of forced circulation by means of a fan, when positive and equable results are desired. Heat is merely a useful accessory to decrease the time of drying by increasing both the rate of evaporation and the absorbing power of the surrounding space.

It makes no difference whether this space is a vacuum or filled with air; under either condition it will take up a stated weight of vapor. From this it appears that the vapor molecules find sufficient space between the molecules of air. But the converse is not true for somewhat less air will be contained in a given space saturated with vapor than in one devoid of moisture. In other words, the air does not seem to find sufficient space between the molecules of vapor. If the temperature of the space be increased, opportunity will thereby be provided for the vaporization of more water, but if it be decreased its capacity for moisture will be reduced, and visible water will be deposited.

The capacity of air for absorption —or more properly speaking, the amount of vapor which a given space will contain—increases rapidly with the temperature. It is principally for this reason that heat is such a valuable accessory to the drying process. Upon these principles has been developed the blower type of kiln in which all the heating surface is massed in connection with the fan which forces the warm air into contact with the material to be dried.

25 TON STANDARD GAUGE SWITCHING LOCOMOTIVE

Electric Locomotives

THE accompanying illustration shows a view of a 25-ton switching locomotive built by the Jeffrey Manufacturing Company, Columbus, Ohio, for use in handling freight cars for the Cerveceria Cuauhtenac Brewery, of Monterey, Mexico. This style locomotive takes the same electrical equipment as the mine type, the only changes being in the side and end frames and the addition of a platform and suitable cab to accommodate the conditions incident to surface work. The motors are of the waterproof steel frame type, having drum-wound armatures, laminated pole pieces, oil lubrication with auxiliary grease boxes and liberal wearing surfaces.

These locomotives are built in sizes from 10 to 30 tons with two motors; in larger sizes with three and four motors, arranged with rigid frame or with double trucks having flexible wheel base, depending entirely on the conditions.

Graphite in Winter as an Aid to Better Lubrication

ALMOST any bearing that requires oil in it will work harder in winter than in summer, as the oil is bound to be more viscous when cold than when warm. It is for this reason that experienced men who have tried it suggest that a possible solution of difficulties in lubrication may be found in the use of flake graphite along with some thin mineral oil. The lubrication will be as good, if not better, and the drag and slowness will disappear.

The Effect of the Temperature of Gases Upon the Operation of Mechanical Draft

(From "Mechanical Draft," by J. H. Kinealy.)

INASMUCH as the fan of an induced mechanical draft apparatus handles the hot gases instead of the cool air for combustion, the fan acquires a temperature almost equal to that of the gases, and as this temperature may be as high as 600 degrees or even higher it is necessary to use water-cooled bearing for it. Further, as the volume of the gases increases with the temperature, the higher the temperature the greater is the volume of the gases which the fan must handle; and for a fan with a wheel of a given diameter this means a higher speed of rotation and more power to drive the fan.

The volume of the gases resulting from the combustion of a given quantity of coal when heated to a temperature of about 550 degrees, quite a common temperature for chimney gases, is about twice as great as the volume of air supplied to the furnace when at a temperature of about 80 degrees. Whatever, then, reduces the temperature of the gases before they enter the fan, reduces the volume per pound of the gases, and therefore increase the weight of gases which the fan can handle when runing at a given speed, because the capacity of a fan like that of a pump depends upon its volumetric displacement per unit of time. The greater the weight of gases handled per minute the greater is the weight of coal burned per hour; and, hence, the greater the capacity of the boiler plant as a steam producer. In other words, cooling the gases before they reach the fan not only increases the draft for a given speed of the fan, but also increases the amount of coal which may be burned per hour; and, hence, increases the capacity of the plant as a steam producer, and does not materially change the power required to run the fan. And if the gases can be cooled by increasing the heating surface of the boilers or by the use of an economizer or an air heater, the heat taken from the gases during the cooling process is saved and the steam generated by the plant is obtained more economically.

With a chimney the case is very different, since a reduction in the temperature of the gases entering the chimney means a reduction in the draft as well as a reduction in the volume of gases flowing out of the chimney. If the reduction in the temperature be great, the draft may not be great enough to overcome the friction of the air through the fire and the friction of the hot gases through the various flues and the chimney. The result is that because of the reduction of the draft and in spite of the less volume of gases to be handled by the chimney, the amount of coal that can be burned in the furnace may be, and is very likely to be, unless the draft in the first place was greater than necessary, less after the gases are cooled than before. This means, of course, a decrease in the capacity of the whole plant as a steam producer, and may necessitate an increase in the whole plant in order that it may generate the required amount of steam per hour. And the interest on the first cost and the depreciation and repairs on the addition to the plant may more than offset the saving made by cooling the gases. Of course, when the chimney is high enough to give the required draft with the lower temperature of the gases, cooling them brings about a saving in the operation of the plant by reducing the quantity of coal necessary to be burned in order to evaporate the required amount of water.

At the coming convention of the American Society of Mechanical Engineers in New York, there will be a special discussion upon the subject of "Gas Power," which will include papers upon "Low-Grade Fuels in the Gas Producer," by F. E. Junge, and "Duty Test on Gas Power Plant," by J. R. Bibbins.

The Commercial Exploitation of Power

THE development of the manufacture of power from waste furnace gases has been retarded for reasons which, although not directly mechanical, may be mentioned because they bear directly upon all plans for the development of power as a by-product of other industrial operations. The distribution and sale of power forms an important and peculiar business by itself. In some respects it resembles the supply of water or of illuminating gas, and it is for such reasons that it has been sometimes considered as especially adapted for municipal control or ownership. It involves dealings with many customers of different kinds, and when once started on the service must be maintained without interruption and with a minimum of irregularity.

Under such conditions the power supply becomes a rather onerous department of a business primarily devoted to some other purpose, and few iron manufacturers are willing to enter into the utilization of a by-product of their main business when they realize that it involves them in the undertaking of a new and intricate business from which it may be difficult to escape should it prove undesirable. The solution of this part of the problem appears to lie in the adoption of methods which have been found successful in connection with the development of great hydro-electric power centres; that is, to place the distribution and sale of the power in the hands of an auxiliary organization devoted entirely to the purpose. There is little difficulty in maintaining a sufficient supply of gas of an approximately uniform quality from blast furnaces when there are a number of furnaces in operation, since the discharge from the various furnaces may be mixed and cleaned and controlled in such a manner that no serious interruption to the operation of the engines using the supply need be feared. The true method of developing this important source of power appears to lie, then, in the organization of a power company, independently of the iron works, this company taking all the waste gases from the iron works and assuming itself the responsibility of the power house with its gas engines, dynamos and electric distribution system, and handling the sale of the power on its own account under its own business management.

Another source of gas power which as yet has not been developed, but is awaiting exploitation, appears in the enormous quantities of waste slack coal and culm which have accumulated about the coal mines. Much of this material is suitable for the manufacture of power gas adapted for use in gas engines, but it cannot be placed upon the market at a price which warrants its use. The great difficulty in all the plans which have been proposed to convert this material into a marketable fuel has been the question of transportation, or rather of transportation costs. Artificial fuels made from coal dust are generally more friable than the original coal lumps, and the cost of transportation in any case becomes the controlling element in the cost of power made directly from such fuel. Such low-grade fuels may be utilized, however, by their conversion into fuel-gas at the mines, the gas itself being delivered through pipe lines by pumping to the manufacturing centres where it can be utilized for power manufacture. That gas can be so pumped over long distances at a moderate cost has already been demonstrated by the successful operation of pipe lines for the transportation of natural gas. A similar system can undoubtedly be applied to the delivery of produced gas from the mines to the cities, and by a simple arrangement of relay pumping stations, the pumps being operated by gas engines taking their supply from the mains, the pressure in the pipe line need not be high.—"The Forum."

The Problem of the Air Compressor

CORRECT practice in industrial lines is of slow development. Never are the best means or the best methods first thought of or adopted, and the later ways of doing things generally show best improvement and advantage over all which have preceded them. The beginning of any new operation is usually small and provisional, and the devices first employed are often crude, because of the suggestion that they will be only temporary. The makeshift is the instinctive first thought, rather than the last of the race, and thoroughness and economy are the result only of long and tedious education.

There is the lubrication of machinery, for instance. We may suppose that it was known almost from the first that oil is good to stop the squeaking of a wheelbarrow, and it soon comes to be understood, no doubt, that oil will also make things run easier, and so the hand oil can came into existence to be used when thought necessary, and often under compulsion to relieve cars or muscles. To-day the need of lubrication is recognized as constant, and continually running plants are provided with a continuous circulation of the lubricant. Oil may be said to be now recognized as a component part of a machine wherever rubbing friction occurs, and has its place and its function just as the connecting rod has.

The air compressor—speaking here chiefly of the steam-driven machine—is a curious and pertinent illustration of this habit of first adopting the crude and the inefficient, and of the later gradual adaptation of the machine to its complicated and exacting duties. The rock drill came into existence, and it at once demanded a supply of compressed air for driving tunnels, sinking shafts and for general mining work. Its demands were so urgent that practically anything which would go and keep going, maintaining the required air supply, was at first accepted. Not only were the earlier styles of machines crude and wasteful, but they were surprisingly long retained, and only quite recently has the demand for economy and complete adaptability in air compressors, as in other machinery, decidedly asserted itself.

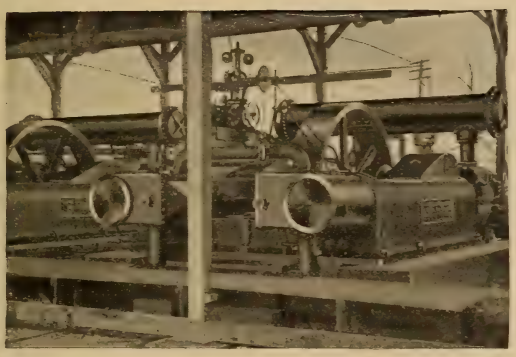
The steam-driven air compressor has to satisfy many more conditions than at first glance may appear, and the designing of such a machine is a much more complicated task than that of any steam engine or any water pumps. The range of opportunities, either of waste or of saving, is decidedly greater in the air compressor than in the steam pump or the stationary steam engine. Even in the steam end of the machine—looking at that alone—the requirements are quite different, for while the stationary engine must maintain a constant speed under a variable load, the compressor has a practically constant load per stroke, while the total amount of work required in any given time may vary widely, thus necessitating as the most obvious solution a continually varying speed.

When the steam and the air cylinders are in a straight line, the pressure in the one being directly applied to the overcoming of the resistance in the other, we have in every stroke the continually diminishing pressure in the steam cylinder opposed to the continuously increasing resistance in the air cylinder, so that while the total pressure in the steam cylinder may be quite sufficient for the work required of it, the distribution of it is unfortunate, and somewhere in the machine must be provided a means of storing the surplus of force at the beginning to be given out again at the end of the stroke. In duplex machines the two sides help each other over these hard places, so that if the fly-wheel is depended upon to be the equalizer and distributor, a lighter wheel is required for the two sides of the machine than would be required for either side alone.

"IMPERIAL"

TYPE TEN

AIR COMPRESSORS

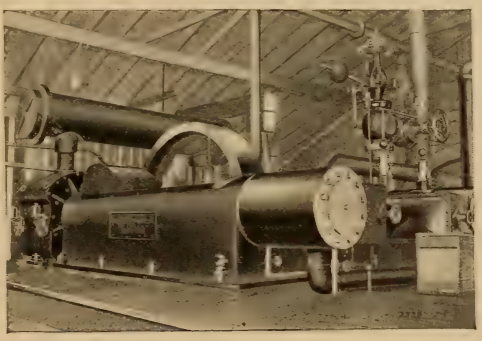


Two of nine "Imperial" Type Ten Compressors on the Panama Canal. 183 Ingersoll-Rand Rock Drills are also used on the Canal.

Here are given two typical instances of their success in heavy contract service, which is but one of the many fields in which these compressors are eminently successful. They are equally adapted to service in the mine, shop, quarry, etc.

A powerful, compact, self-contained machine of high efficiency with Corliss Intake Valves, Cushion Discharge Valves and automatic bath lubrication and with a greater capacity per unit floor space than any other type.

OIL ECONOMY. The enclosed self-oiling features of the "Imperial" result in an oil economy unequaled by any other type. A RECENT RECORD SHOWS WHERE 12-IN. STROKE "IMPERIAL" RAN FOR EIGHT MONTHS, 18 HOURS PER DAY, WITH A TOTAL CONSUMPTION OF TEN GALLONS OF OIL (MACHINE AND CYLINDER), OF WHICH SIX GALLONS WERE RECLAIMED AND FILTERED FOR FURTHER USE.



"Imperial" Compressor on the Tidewater Railway Construction. This is one of 20 Ingersoll-Rand Air Compressors used on this work. 350 Ingersoll-Rand Rock Drills are also used.

INGERSOLL-RAND CO.

CHICAGO PHILADELPHIA 11 BROADWAY ST. LOUIS EL PASO
CLEVELAND HOUGHTON **NEW YORK** PITTSBURG BOSTON
SEATTLE SAN FRANCISCO BUTTE SALT LAKE BIRMINGHAM DENVER
MONTREAL JOHANNESBURG LONDON BERLIN MELBOURNE PARIS

V29

Simple Fuel Handling Appliances

IN considering the various advantages accruing in the installation of gas power over steam, the economy in fuel naturally holds first place. Generally speaking, the fuel consumption of a gas-power plant may safely be taken at about one-half that of a steam plant of the same power. This, however, is but one of the economies effected by the gas-power system. The steam plant requires numerous auxiliaries, and, in nearly every case, some mechanical method of handling the fuel is necessary if the best efficiency, so far as labor is concerned, is to be secured. The gas plant has its fuel to be handled also, but since the consumption is reduced one-half, there is a correspondingly smaller amount of fuel to be handled and the same reduction in the amount of ash to be removed.

The modern steam plant of to-day is frequently equipped with mechanical conveyors, delivering the coal to overhead bins, and permitting it to be fed gradually to automatic stokers, an arrangement which has much to recommend it. A similar arrangement is employed to remove the ashes, and with such an equipment much of the laborious work of the stoker is removed.

The gas producer, whether fed in quantity, or by a sprinkler system, is also best provided with a mechanical handling device, but in most cases a much simpler and less costly equipment will suffice. A plan which has been successfully used in a number of cases is that using some form of standard hoisting appliance, suspended from an overhead tramrail, and carrying one of the various commercial forms of tipping or grab buckets. The capacity of the bucket may be chosen to correspond with the proper quantity of fuel to give the proper charge, and the tramrail may run over a whole line of producers, feeding one at a time, the rotation thus kept up conducing to uniformity in operation.

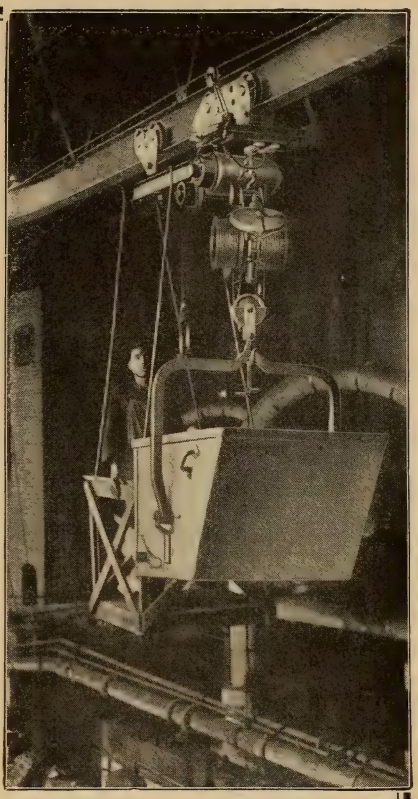
The slow rate of combustion and the moderate amount of fuel consumed, renders it possible for such conveying apparatus to be operated wholly by hand when the plant is of moderate size. For suction-producer plants, a simple chain block carrying a tip bucket will do very well. When a larger system is in use the Triplex block has been found effective, keeping the work within the capacity of a single man, and such an outfit is found sufficient for plants in which the total fuel consumption does not exceed 100 tons per day.

When more than 100 tons of fuel are to be handled in a day it is better to install some mechanically operated hoist, and in such cases an electric hoist is ample for the purpose. For large gas-power plants an overhead tramway, fitted with an electric power hoist and grab bucket, and provided with a motor-driven trolley, constitutes a complete system both for feeding the producers with fuel and for the removal and transport of ash.

Such a system has the great advantage of economy in operation, and of moderate first installation cost. It is made up of parts which are already commercial products, and which do not have to be designed or built for the especial purpose. This makes both for moderate cost in the first place and for promptness in original installation. Such a system is also of much value in connection with the repair and installation of the producers themselves, and the tramrail and electric hoist, if put in place before the producers are built, will aid greatly in the work of erection.

It thus appears that the advantages of gas power are not limited to the mere economy of the apparatus in the conversion of heat into work, but continue along the entire line of installation and operation, and thus bear not only upon the cost of fuel, but, what is far more important, the entire cost of installation and operation of the entire power plant.

Fuel Handling Apparatus for Gas Producer Plants



The problem of economical handling of coal and ashes in gas producer plants is not always well solved by installing mechanical conveyers.

For small size suction producers a Yale & Towne TRIPLEX BLOCK running on an overhead I beam track and carrying a tip bucket, will handle satisfactorily and economically up to 100 tons per day. For larger tonnage a Y & T ELECTRIC HOIST installed on a motor-driven trolley will afford the cheapest efficient handling service.

The illustration shows a 2-ton hoist of this kind with trailer cage for operator. This cage is dropped to a point where the operator can control the dumping movement of the bucket as well as the movements of hoist and trolley. A lifting speed of 20 to 25 ft. and a traversing speed of 350 ft. per minute may be attained. The cheapest labor can operate the hoist.

¶ *For further particulars ask for our Chain Block and Electric Hoist catalogs, mentioning this advertisement.*

The Yale & Towne Manufacturing Co.

9 Murray Street, New York

Foreign Warehouses—Fairbanks Co., London & Hamburg; Fenwick, Freres & Co., Paris; Alfred H. Schütte, Köln a Rh.; F. W. Horne, Yokohama, Japan.

Fuel Handling for Gas Producers

IN making comparison between steam power plants and gas power installations there are several elements to be considered, and it is only by taking all of them into account that a correct judgment as to the relative value of each can be made. The greater thermal efficiency of the gas engine over the steam engine is well known and conceded. Except in regions where natural gas is available, however, the question of the production of the fuel-gas enters into the problem, so that the gas producer may well be compared with the steam boiler of the steam plant. Here questions of installation costs and maintenance come into the account, and with the gas producer as with the boiler plant there is fuel to be handled and ash and refuse removed.

With the gas producer the method of charging differs so materially from the boiler furnace that the method adopted for delivering the fuel must be modified to suit the special conditions. Some producers are charged intermittently, while others have a continuous feed, an automatic spreading device sprinkling the fuel over the top of the charge at a rate proportional to the consumption. In both cases the charge must be brought at intervals and delivered at the right moment, in the right place.

As in the case of the boiler house, this work is best done by special appliances which have been developed by experience with working plants out of the necessities of the work. The laborious work may practically all be performed by machinery, leaving only the direction of the apparatus to the men in charge, and rendering the handling of large amounts of fuel a simple and convenient operation.

Assuming that the fuel is stored in bulk, the appliances for receiving it from boat or car, and conveying it to the storage bins do not differ from those employed in any well arranged steam plant. Coal-handling towers on the water front, conveyor plants at the railway, may be used, as conditions indicate, and the fuel once in the storage bins, it may be drawn through chutes as wanted for the gas producers.

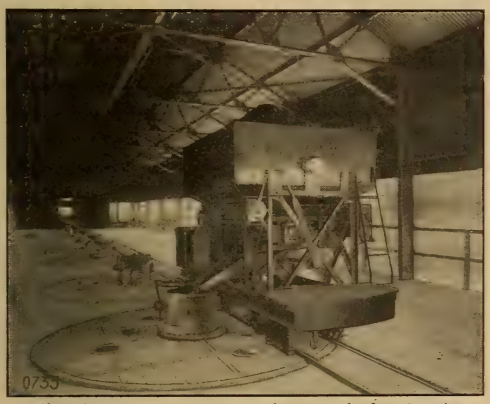
In nearly every case, however, it is necessary to have the gas producers situated some little distance from the coal storage, and hence a suitable section of industrial railway becomes the most convenient means for conveying coal from the discharge chutes to the dump into the gas producers.

The most complete equipment for this work is found in the electric locomotive, provided with special coal car, running on a narrow gage industrial railway. By having the coal car built in combination with the locomotive the entire apparatus may be readily handled and the fuel conveyed and delivered exactly as needed.

For service of this sort the overhead trolley or the third rail are neither of them well adapted, and the best arrangement is the storage-battery locomotive, as being self-contained and free from the inconvenience and danger of live wires, or third rail about the gas-producer plant. In both the steam plant and the gas-power plant, therefore, we have analagous parts. The gas producers themselves correspond to the boiler installation, and the gas engines themselves practically require about the same space and general arrangement as the steam engines, while both demand in about equal degree the service of a modern and adequate fuel-handling plant, including apparatus for receiving and storing the coal and either conveyors and their attachments for delivering the fuel to the furnaces, or else the convenient electric storage-battery locomotive, operating upon industrial railway, and serving as many producers as may be installed in any portion of the establishment.

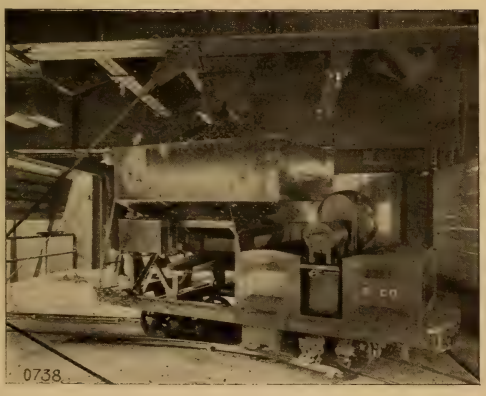
Charging Gas Producers

HUNT METHOD



Electric Storage Battery Coal Car ready for charging.

Charging a gas producer.



Charging the larry of a Storage Battery Coal Car.

C. W. Hunt Company

(Established 1872)

Main Office and Works
WEST NEW BRIGHTON, N. Y.

City Office, 45 BROADWAY, NEW YORK

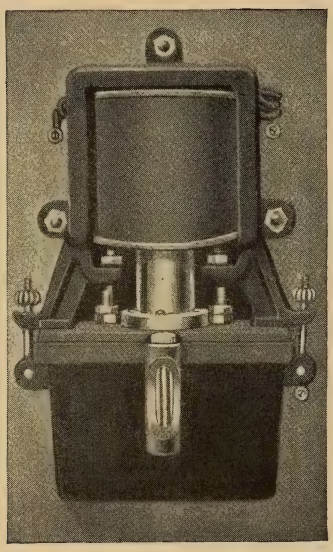
One of the most convenient, economical and simple methods of charging gas producers is by The Electric Locomotive Coal Car, running on an "Industrial Railway." It is specially designed for handling coal from the storage bins to gas producers.

The Locomotive runs under an elevated storage bin, and coal is loaded into the larry through suitable valves. The "Industrial" track runs over the top of the gas producers, into which the locomotive spouts the coal direct. The coal storage bin can be situated in any convenient position where the "Industrial" tracks can reach them. The entire operation of the machine requires the services of but one man.

Self-Starters for Electric Motors

ONE of the most interesting developments of the electrical industry is that relating to automatic starting devices for electric motors. To be able to have a motor start or stop automatically under certain predetermined conditions means, very often, the saving of one man's time in cases where the operation is repeated at short intervals, and where this is not the case the automatic device is, nevertheless, preferred in many instances because it never forgets.

As a practical illustration of the usefulness of the self-starter a motor-driven pump affords a good example.



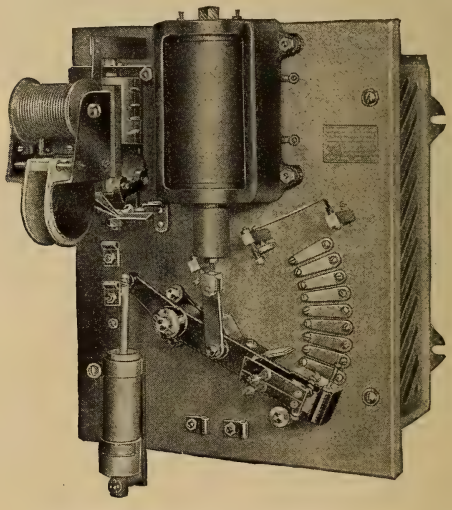
SELF-STARTER FOR ALTERNATING CURRENT MOTOR

Where the motor is started by a manually operated starting rheostat, someone has to remember to start the motor when the water gets low in the tank, and to stop it when the tank is full. Motors equipped with self-starters require no such attention, since by means of a float, switch or pressure regulator, the self-starter is energized when the water in the tank reaches a predetermined high or low level, and operates to open or close the circuit to the motor.

According to *Mines and Minerals*, 17 tons of water are raised from the anthracite mines of Pennsylvania for every ton of coal mined. Motors operating these mine pumps are sometimes installed in out-of-the-way places, and formerly when an interrupted current brought the motors to a standstill, it was necessary to send a man to start them up again when the voltage returned to the line.

This work is now preferably performed by self-starters which automatically cut resistance into the armature circuit on failure of the line voltage (thus protecting the motor from a sudden inrush of current) and automatically cut the resistance out again when the voltage is again normal.

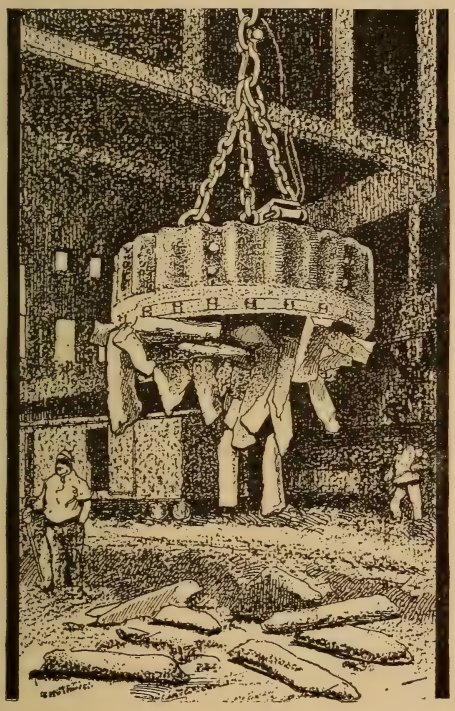
By combining a dash pot with the self-starter, the time required for acceleration of the motor can be so adjusted that the motor will start smoothly under any load. This is sometimes very desirable, as, for instance, in elevator service, where sudden starts and stops must necessarily be avoided.



SELF-STARTER FOR ELECTRIC ELEVATORS

The accompanying illustrations show two types of self-starters, made by the Cutler-Hammer Mfg. Co., of Milwaukee, Wis. This company makes a specialty of electric controlling devices and have recently developed an extensive line of self-starters for both alternating and direct-current motors.

LIFTING MAGNETS



The Carnegie Steel Company bought their first Cutler-Hammer magnet in January of this year.

We heard nothing more from them for six months. They were trying it out.

In June they ordered a second magnet, similar to the first. In August a third.

This company has used lifting magnets of various makes for years—they are familiar with every magnet made, and were among the earliest to order of us when the Cutler-Hammer lifting magnet was first placed on the market.

If the first magnet we built for them was not better than any they had ever used before, would they have ordered a second? If the second had not been as good as the first, would they have purchased the third?

Cutler-Hammer Lifting Magnets are sold under the following:

"Three-Way" Guarantee

1.—AS TO WEIGHT: The magnet we will build for you will be as light as is consistent with proper design and its weight will be guaranteed *not to exceed* that of any comparable magnet.

2.—AS TO EFFICIENCY: The lifting capacity of our magnet will be guaranteed to *exceed* that of any comparable magnet now in use.

3.—AS TO OPERATING COST: The operating cost per ton of material moved will be guaranteed to be *less* with our magnet than with any comparable magnet.

Send for illustrated booklet. When writing, state size of magnet desired, and nature of material to be handled.

CUTLER-HAMMER CLUTCH CO.

Makers of Magnets and Magnetic Clutches

MILWAUKEE, WISCONSIN

NEW YORK OFFICE: 136 LIBERTY ST. CHICAGO OFFICE: MONADNOCK BLOCK PITTSBURG OFFICE: FARMERS' BANK BLDG. BOSTON OFFICE: 176 FEDERAL ST.

Technical Education

IT is not so very long ago that engineers and mechanics were divided into the two classes, the so-called "practical" and "theoretical" men. Each of these looked down upon the other, the theoretical man considering the practical man as a sort of greasy mechanic, much in the same supercilious manner in which line officers in the navy still look down upon the members of the engineer corps; while the practical mechanic considered the possessor of a technical education as a man of "high science," wholly worthless when any real work was to be done.

Time has wrought its changes, and to-day the latest developments of the science of engineering find their way almost at once into the practical and commercial industries, and things have to be done which were unknown but a few years before, and of which the old-time practical man is necessarily ignorant.

At the same time, transformations are going on in shop practice and machine methods which render much of the old laboriously acquired shop experience obsolete. The apprentice, after he had served his initiation in sweeping and cleaning up, was formerly "introduced" to the chisel and hammer, and allowed to bruise his knuckles learning how to handle those once essential tools. Later came a course in filing and fitting, and with all this he was supposed to acquire experience in calipering sizes by the sense of touch, in connection with ancient calipers and roughly graduated foot-rules, and thus slowly and painfully to learn to do things by hand which are now far better performed by shaping and grinding machines, by drop press and by limit gauge. The practical training in the shop must still continue, but it now has to keep pace with the new tools and improved methods which are placed at its disposal.

In the meantime, the theoretical man has had to face changing methods and appliances. The technical school of to-day has to fit its students to fill the jobs which are awaiting them as they are graduated from their studies. Formerly the young graduate often found it wise to keep his mouth closely shut as he went about looking for a start in life, otherwise he found it an adverse recommendation in the eyes of many employers. To-day the professor of engineering is sought by the employer and urged to supply young graduates for immediate and active shop service.

The causes for this change of opinion are to be sought on both sides. We have already seen how the changes have occurred in the shop, and the developments in the technical school have been no less important. Theory is taught indeed, but as a means to an end, and not as all-sufficient in itself. Mr. Swinburne has effectively labeled what was once known as "pure" science by the much more vigorous title of "raw" science, as a thing incomplete until it is applied to some useful end, and to-day engineering is considered as synonymous with applied science.

Under such conditions the material prosperity of a country is closely bound up with the prosperity of its technical schools and colleges, and these institutions are taking their proper position in the community as places where young men are taught to do things, to add to the wealth of the world by developing its material resources, and to raise the standard of human existence by their efforts.

Manufacturing News

Another Manufacturer of Large Gas Engines

AS an indication of the rapid development in the manufacture of big gas engines and the importance of the field occupied by this type of prime mover, it is of interest to note that another manufacturer of large Corliss steam engines has actively taken up the manufacture of gas engines, and is bidding strongly for engines in medium and large sizes.

The Wisconsin Engine Company, with works at Corliss, Wis., which has built some very large and successful Corliss steam engines, is building gas engines for all services in sizes from 400 B. H. P. to 5,000 B. H. P. The engines utilize natural gas, producer gas, coke-oven or blast-furnace gas in the Otto cycle (4-cycle), and are of the horizontal tandem and twin-tandem, double-acting type. This company controls the Sargent patents on internal-combustion engines, and has employed Mr. Charles E. Sargent as the engineer of its gas engine department. Mr. Sargent has a wide reputation as an engineer, and in 1898 designed the first successful horizontal tandem double-acting gas engine, which was a wide departure from the accepted practice of those days, when the most prominent manufacturers of gas engines declared such a type was impracticable and doomed to failure. However, the largest and most successful gas engines are of the horizontal twin-tandem, double-acting, 4-cycle type, and, with one exception, this is the only type in which large units are being built in the United States to-day.

The gas engines built by the Wisconsin Engine Company bear some of the distinctive features of their big Corliss engines, and utilize in design most of the Sargent patents. The design is remarkably simple, and embodies features which are of considerable interest to the engineer and power user, e. g., there is but one poppet valve for each explosion chamber; and as this is located on the bottom of the cylinder, the cumbersome and unsightly air and gas pipes, as well as the stairs, galleries and railings found on most horizontal tandem engines, are entirely eliminated; provision is made for preventing the dangerous pressures caused by possible pre-ignitions, and the engines are started automatically.

Tests of even small Sargent engines show a heat consumption of less than 9,000 British thermal units per brake-horse-power-hour.

This company has recently shipped some large steam engines to such concerns as the Illinois Steel Company, Jones & Laughlin Steel Company, Packard Motor Car Company, American Sheet & Tin Plate Company, Amoskeag Manufacturing Company, New Hampshire Spinning Mills, National Tube Company, City

of Milwaukee, Carnegie Steel Company, American Woolen Company, United States Envelope Company and the Carnegie Natural Gas Company, and has built up an unusual reputation for shipping "on time." It promises to do as well on gas engine orders.

West Shore Railroad

THE electrification of the West Shore Railroad between Utica and Syracuse has been closely watched. Special attention has been attracted to it on account of its 50,000-volt transmission line, the adoption of an inverted, protected third rail, and the hydro-electric development from which power is supplied.

In Bulletin No. 4,546 the General Electric Company, Schenectady, N. Y., has issued a handsomely bound pamphlet of 24 pages, in which the installation is very completely described. The bulletin is profusely illustrated with views of the trains, interior of the cars, transmission lines, exterior and interior of sub-stations, plans of the buildings and wiring diagrams, and details of the track construction. Not the least interesting feature of the pamphlet is a comparison of two train sheets, one showing the operation before electrification and the other after, where the increase in traffic with the same track capacity is very strikingly shown. The bulletin cannot fail to be of interest to all steam railroad engineers, as well as those actively engaged in electric traction.

Activity in Machine Construction

IN view of the generally unsettled conditions existing in business circles throughout the country during the past few weeks of financial stringency, a statement of shipments made from the works of the largest engineering and machinery building company of the United States for the six months preceding November 1 carries more than ordinary interest and significance. During this period the Allis-Chalmers Company sent out machinery, on orders, as follows:

	Pounds.
May	23,772,242
June	22,139,757
July	24,225,760
August	26,006,434
September	26,268,764
October	27,821,682

From these figures it will be seen that, while there has recently been some cessation in "new business," viz., contracts for future fulfillment, the receipt and installation of machinery by industrial, lighting and power companies indicates continued progress. It required nearly 5,000 cars to transport the 150,234,639 pounds of machinery mentioned above from the works of Allis-Chalmers Company to the various places where it was to be operated, and, of course, even more than this number of cars was used for bringing in the raw materials, fuel, lumber for patterns, etc., which are necessary in the manufacturing process.

Testing Rails, Not Locomotives

REPORTS which have recently appeared concerning certain tests the Pennsylvania Railroad has been making on the West Jersey & Seashore Railroad near Clayton, N. J., have created an entirely erroneous impression. It has been stated that the company was racing steam and electric locomotives, with a view to determining the speed capacity of each type. The Pennsylvania Railroad has other, more accurate and much less dangerous methods of testing the speed of locomotives than trying them out in such a manner as this.

Furthermore, the types of electric and steam locomotives which have been used in these experiments were not designed primarily for speed, and any inference based on their performance in this regard would be incorrect. What the company is doing is this: Experience indicates that the operation of electric locomotives, owing to their lower centre of grav-

ity, has an effect upon the track entirely different from that due to the action of steam engines. In order to ascertain the exact nature and extent of this pressure upon the rails, the motive power department has devised the apparatus which is being utilized at Clayton.

A stretch of track about 166 feet in length has been equipped with rails and cast-steel ties, designed and made especially for this purpose. Instead of attaching the rail to the ties by spikes, a special form of block has been substituted, which allows a slight movement of the rails as the engine goes over it; this movement registers the force with which the flanges of the wheels strike or press against the rails. It is expected that a large number of experiments with this apparatus will show the company quite accurately what the effect is of either steam or electric locomotives, moving at different speeds over either straight or curved track.

Necessarily, to make these tests the engines must move at different speeds, and at all times each attains its maximum speed.

An electric apparatus has been devised to measure the precise amount of time elapsing while the different locomotives pass over this 166 feet of track, in order that in computing the effect upon the track the exact speed attained may be known. The steam and electric locomotives, however, go over the track at different times, and there is no element of contest as to speed between the two types. The matter of speed is purely incidental to the main purpose of the tests, which is to enable the company, in planning its electric installations in New York, to design a track so safe as to be absolutely secure against any form of locomotive that may be utilized.

Concerning Lifting Magnets

WITH the exception of articles which have appeared from time to time in this and other technical publications, very little has been printed on the subject of lifting magnets. Those interested in these labour-saving devices will, therefore, welcome a 32-page pamphlet just issued by the Cutler-Hammer Clutch Company, of Milwaukee, in which the subject is very fully treated. The booklet in question contains a number of full-page illustrations, showing lifting magnets handling pig iron, steel stampings, castings, scrap and other material, together with diagrams, data on current consumption, information on lifting capacity of magnets, etc. A new cable take-up device is also pictured and described, and reference is made to the Cutler-Hammer system of control by which the strong inductive reaction or "kick" which occurs when the circuit is suddenly opened on a magnet coil, is automatically shunted to a discharge resistance, thus protecting the magnet insulation by dissipating the energy of the induced voltage outside of the coil itself.

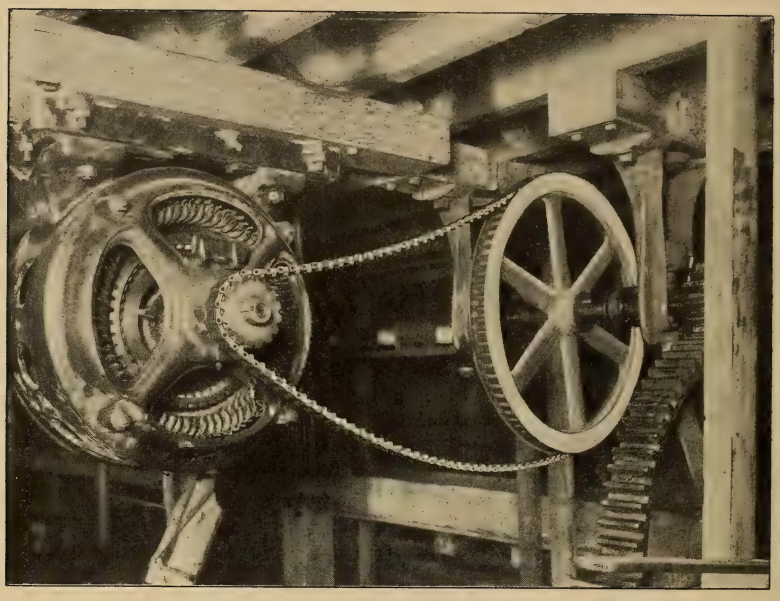
The Schmidt Silent Drive Chain

DRIVE CHAINS, known as "Silent Chains," become very important in the power transmission field. They have this position because they are silent, and due to their ability to adjust themselves to the wheels as they lengthen, retaining their full efficiency until completely worn out. At the same time, they give a positive, flexible drive on short and long centres, at slow and high speeds, unaffected by damp, grease, dust or heat.

The Schmidt chain, herewith illustrated, is the latest development of this type. It combines great capacity, durability and simplicity of construction, and runs smoothly and silently with the least consumption of power.

It is constructed of multiple toothed links stamped from special high carbon steel, case-hardened steel pins, and in retaining links.

The tooth of the link is placed central between the pins, giving a

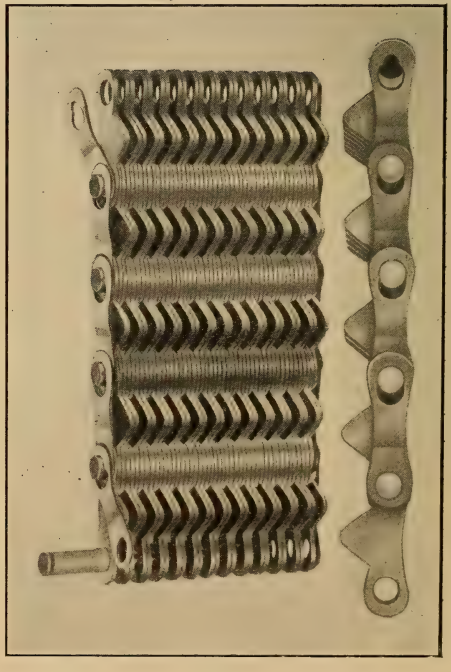


THE SCHMIDT CHAIN DRIVE ATTACHED TO INDUCTION MOTOR

straight path for the stress to follow. Consequently, the links being straight, are in tension only, and will not bend and change their pitch under excess or suddenly applied loads. It follows that for a given load the chain is lighter, giving less dead weight and high efficiency. The faces under the pins are of a sufficient angle so as to clear the corners of the wheel teeth and adapt the chain for any size wheel.

The outer end of the pin orifice in the links has the same radius as the pins. The links, therefore, always have arc bearings on the pins, giving a large bearing surface, and doing away with the excessive wear in a new chain, resulting from the use of a circular hole of larger diameter than the pin, which gives but a line bearing until the metal wears and forms a seat for the pin.

The method of retaining the pins, exclusively used in these chains, is novel and interesting. They are not riveted, but are retained by means of special edge links, called retaining links. These are thinner than the chain links, and have one hole keyhole shaped which passes over the end of a pin and enters the circular groove. The retaining links are offset and overlap, and lock each other, as well as the pins, in place. By this



SCHMIDT PATENT SILENT DRIVE CHAIN

construction the chain is securely held together, and yet is easily detachable for general overhauling, or changing its length, without the use of tools.

The pins require no annealing at their ends, and are consequently free from soft spots and resist wear equally for their full length.

The wheels on which these chains run have symmetrical cut teeth, the number being limited only by the capacity of the cutting machine. Very large speed ratios are consequently possible, 20 to 1 being well within the limits. A drive can readily be reversed, and the chains need not be placed on the wheels in any explicit manner.

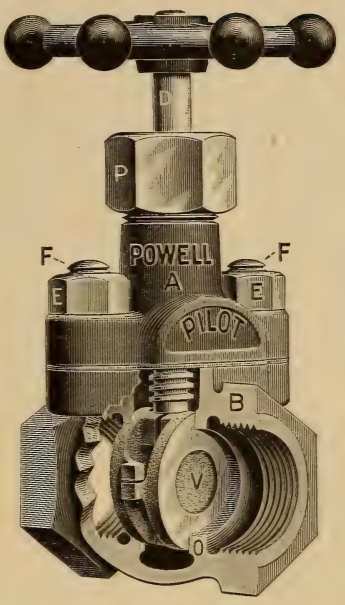
The Schmidt drive chain also has the faculty of riding out on the wheel teeth, as their pitch lengthens, automatically forming a larger pitch circle, and retaining their original efficiency, greatly increasing their life. The chains, when engaging or leaving the wheels, clear the teeth, eliminating wear and friction.

These chains are broadly patented, and are manufactured by the Schmidt Drive Chain Company, of No. 265 Broadway, New York City.

An Improved Gate Valve

THE "Pilot" iron body gate valve is another addition to the already long list of steam specialties manufactured by the Wm. Powell Company.

The illustration shows a strong, compactly built valve with every detail carefully worked out. The iron body is built for service, and is designed with heavy lugs on either side of the neck, carrying stud bolts *F;* the bonnet cap *A* has corresponding lugs drilled to template, which insures a perfect joint and constant alignment at all times, and also allows the bonnet to be replaced without unusual care after taking apart for inspection or repairs. Two semi-finished hexagon nuts *E*, large enough to admit wrenching down hard, with a joint of the best packing material



THE POWELL PILOT VALVE

between the faces of bonnet and body, make an absolutely tight joint for all pressures up to 100 pounds.

Note the large brass packing nut *P*, affording plenty of room for packing material.

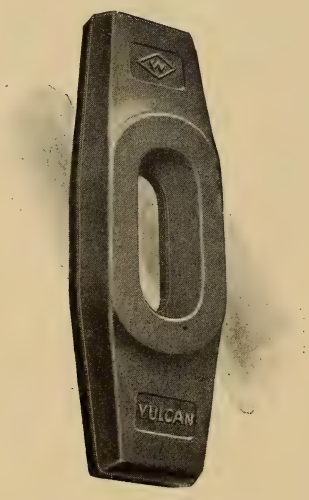
The brass stem *D* and bonnet are chased and cut to a true Acme thread of unusual length, the best for wear. The length of thread keeps the stem in a true axial position at all times, whether open or closed.

The discs are double, not a single, wedge, with ball and socket back, making them adjustable. They are hung in recesses to the collar on the bottom of the stem. The discs, working in a tapering seat, expand or collapse in opening or closing, making a valve that will close down tight without straining or open easily, no matter what the conditions may be.

The Powell Pilot gate valve is also made all iron, that is, discs, stem and packing nut are of iron; not a particle of brass used in its construction anywhere. This all-iron Pilot gate valve will be found especially valuable in controlling ammonia, cyanide solutions, acids and all other liquids or gases that attack brass.

The Allis-Chalmers Company at Jamestown

ALLIS-CHALMERS COMPANY, of Milwaukee, has been awarded the gold medal for electric generators and motors, issued by the authorities of the Jamestown Exposition, as determined by a jury of well-known technical experts representing leading electrical interests of the country. A second gold medal has also been granted for the good judgment and taste shown in the design and erection of the exhibit, which has been one of the most attractive features of "Machinery Hall." Gold medals have previously been taken by electrical apparatus of this company's build at the Louisiana Purchase Exposition, Paris Exposition, and other exhibitions where there was international competition.



THE VULCAN PLANER CLAMP

Steel Forged Planer Clamp

THE old-time planer clamp, used for securing work to the platen of a planing machine, was usually a crude affair of wrought iron, made in the shop where it was used. In the modern shop it is well understood that it pays to have even the simplest appliances well made from the best materials, and that such articles can be better made by regular manufacturers than by the users.

Messrs. J. H. Williams & Co., of Brooklyn, have placed on the market a standard line of clamping heads, drop-forged from tough, high-carbon steel, the forgings being subjected to special treatment, adding materially to their stability. The general form of the clamp is well shown in the illustration, and it will be seen that the oval hole permits considerable adjustment. The line, as at present made, includes three sizes, varying from 4 to 8 inches total length.

The design of this clamp has been approved by a number of leading machine tool builders as well adapted for lathe, planer, drill-press, milling and boring-machine work.

ALLIS-CHALMERS COMPANY, of Milwaukee, is issuing a bulletin on "Compound Corliss Engines," which contains, besides illustrations of each type, many facts of interest to power users throughout the country. "So far as we are aware," it is stated, "the first compound Corliss engine designed for power purposes was built in the shops of this company, and to Mr. Edwin Reynolds, who for nearly half a century has been so prominently identified with the history of this type, should be given credit for introducing the principle of compounding into general Corliss engine practice. The earliest Corliss engine was built in 1848, and twenty-eight years later the famous "Centennial" engine, which was supposed to embody in its design and construction the very highest development of the engine builder's art, was nothing more than a pair of simple engines. The first Reynolds-Corliss engine, built in 1877, marked the beginning of an epoch in the history of the steam engine. The first compound Reynolds-Corliss was built three years later, and is still in regular operation."

Since then thousands of these en-

gines have been put in service in electric railway and lighting power houses; in large and small pumping stations; in blast furnaces and rolling mills; in textile mills, flour mills and sawmills; in foundries, machine shops and woodworking factories; in newspaper and printing establishments; in office buildings; in technical schools and colleges; in all kinds of industrial plants at home, and in nearly every country in the world Reynolds-Corliss engines have thoroughly demonstrated their good qualities, and its compound engines have contributed largely to the high reputation in which the products of Allis-Chalmers Company are held.

The strong argument in favour of the use of compound engines is their greater economy. The economy of the power plant, as a whole, is, of course, dependent upon the efficiency of boilers, furnaces, stack, etc., as well as upon engine economy; but, assuming the same efficiency of the other parts of the power plant, the economy of the engine will determine the relative amount of fuel required. Under the same operating conditions, a compound non-condensing, as compared with simple Corliss engine, will effect a saving of at least 20 per cent., and a compound condensing Corliss will effect a saving of at least 40 per cent. in cost of fuel. There are few locations where the cost of fuel is so low that such saving will not, after paying good interest on the additional cost of the compound engine, afford a sufficient surplus to wipe out this difference in cost in a very few years.

The importance of this is not confined to the larger plants, for, although the comparative difference in cost may be somewhat greater in the smaller plants, the saving is still large in comparison.

There is a general, though decidedly erroneous, impression among steam users that no great advantage can be gained by compounding unless high steam pressures are used. While it is true that high pressures are conducive to economy in steam consumption, it is equally true that at lower pressures the percentage of saving by compounding is relatively very nearly as great, when engines are run condensing, as at higher pressures. It is true that a compound Corliss will be more economical at 150 pounds than at 100 pounds initial pressure, and it is also true that a compound condensing Corliss, when operating under 100 pounds initial pressure will use 40 per cent. less steam than a simple non-condensing engine under the same pressure. In fact, the great economy of compound Corliss engines was demonstrated and their reputation established at a time when pressures higher than 80 pounds were rarely used. The economy of compound non-condensing engines is less marked at lower pressures, but even at 100 pounds initial pressure a compound non-condensing engine will effect a saving of approximately 15 per cent.

To determine whether it is better to use a compound engine requires careful consideration of the commercial and engineering conditions in each particular case. The compound engine is unavoidably more expensive than the simple engine, against which must be offset the saving in cost of fuel and also in cost of boiler room equipment, owing to the smaller steam-making capacity necessary. The price of fuel and steadiness of operation of the plant have an important bearing in this connection, for, if fuel is inexpensive, or if the engine is to run only a few hours per day or for a short period each year, the annual saving may not warrant the additional cost of the plant. On the other hand, if the engine is to be run steadily, the annual saving, even with low-priced fuel, will more than warrant the additional investment.

Theoretical and Practical Machine Tests

THE essential point of difference in the traditional and perpetual contest between the theoretical and the practical, in which the latter is so generally the winner, is apt to be not that the former is wrong in any particular, but only that its grasp is not all-comprehensive. It does not take into account every detail of function which might help to affect or determine the ultimate result. This is frequently shown in the tests of engines and machines which are made by college professors and those associated, the reports of which have been apparently the favourite filling for the transactions of the societies, in which are determined the consumption of coal, of water, and sometimes even of oil, with usually nothing beyond.

These reports of fuel economies are innocent enough in themselves, but when they become the sole evidence relied upon in the selection of apparatus for any purpose, they are misleading and cannot alone secure the most efficient and satisfactory service. It happens that, in addition to the consumption of fuel, *the consumption of engineer* is often an important and many times should be the determining consideration. One line of machines may require much more of skill, of care and watchfulness, of minute precision of adjustment, than another, and these things are costly. The consumption of time also, when delays occur from wear, breakage or derangement, and to which also one machine may be vastly more liable than another, may outweigh all the possible savings of coal ten times or a hundred times over. The cost of damaging or destructive accidents, the possibilities of which may inhere in one machine more than in another, may in a minute or an hour wipe out a year's saving at the coal pile. The practical testing of a machine, the testing by continuous, every-day, money-earning work, cannot fail to take full account and impartial account of every particular which may assist in determining the ultimate economy of operation, and the practical test, therefore, is the only one finally accepted.

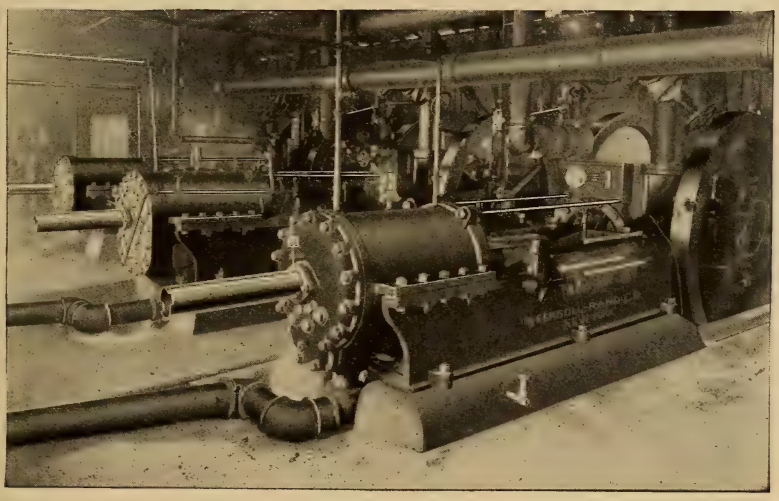
There is a certain air compressor, a pioneer in the larger, more serious and responsible business of air compression, which has held its own phenomenally and is still very much in evidence. It has been built in greater numbers, has held more responsible positions, has done more work, has proved itself more reliable in every-day, all the year round service, as well as for all sorts of emergent, exacting and unusual conditions, than any other in the world. It has been overcrowded, abused, neglected, and its good name has been attacked both openly and covertly, but it has kept on its way with wonderful pertinacity. Its vitality, to those who are not familiar with the various episodes of its career, is perhaps its most wonderful characteristic.

And yet the explanation is simple. The machine is fairly efficient in every detail of its working, but, above all, it is reliable. This reliability is the largest factor and the one given first consideration when ultimate efficiencies are being considered. It has stood the supreme test, the practical test of continuous service, satisfactorily.

We might have what we might call tests of the bodily performance of different animals as compared with the human machine and, according to the function which was given prominence and made the basis of the individual test, a hundred different animals would be separately the victors, yet we find no man on earth who would choose the body of any animal in preference to his own for the sake of the single point of excellence. In himself and with his natural equipment he can do more things, and do them with passable satisfaction, than would be possible in any other way.

STRAIGHT LINE "A-1"

AIR COMPRESSORS



Three Ingersoll-Rand "A-1" Air Compressors on the Tide-water Railway Construction through Virginia and West Virginia. The following list of machinery used on the Tide-water contracts speaks for itself.

Ingersoll-Rand Air Compressors, 20; all other Air Compressors, 8.

Ingersoll-Rand Rock Drills, 363; all other Rock Drills, 93.

This is distinctly the machine for contract work, which demands a compressor of moderate capacity, reasonable in first cost, economical in operation, durable under hard service, cheaply maintained and capable of management by unskilled attendants. Capacities range from 175 to 1,900 cubic feet per minute.

Careful tests on machines of all classes show that Class "A-1" compressors have a higher efficiency—and therefore a better fuel economy than any mechanical valve two-stage straight line type.

These tests are reported in detail in Catalog A-36, sent on request to all inquirers.

AIR TOOLS CORE DRILLS PNEUMATIC PUMPS

INGERSOLL-RAND CO.

CHICAGO PHILADELPHIA 11 BROADWAY ST. LOUIS EL PASO
CLEVELAND HOUGHTON **NEW YORK** PITTSBURG BOSTON
SEATTLE SAN FRANCISCO BUTTE SALT LAKE BIRMINGHAM DENVER
MONTREAL JOHANNESBURG LONDON BERLIN MELBOURNE PARIS

V 30

Electric Traction in the Shop

THE history of handling material in the workshop is an interesting example of gradual development and growth. Formerly cranes, mostly of the jib variety, and constructed largely of wood, were used in the foundry only, and the labouring gang formed a large, expensive, and unsatisfactory element in shop operation. Then the crane gradually worked its way into the machine shop, and even in its early, hand-operated types, gave much relief and saved much time. The development of the electric travelling crane is a matter of recent shop history, and to-day no new shop is planned without provision for runways for travellers in nearly every department, as well as overhead tramrail and general handling equipment.

In the meantime, there has grown up another department of handling machinery, equally advantageous, efficient and important, that of industrial railways and their equipment. The industrial railway is to the surface what the overhead travelling crane is to overhead shop transport, with the additional advantage that it includes what may be termed "inter-shop" transport. The tracks may be laid to deliver to the innermost departments of each shop, and also cover the ground from one building to another, and thus unite an entire establishment into one operative whole.

When such an installation is of limited extent, and the loads are light and not too frequent, manual labour may be used for propulsion, and this method is very generally used within the shop for many purposes. The ease of running and the light resistance with well-made cars and track reduce the effect so greatly that even in this way the labouring force required may be diminished to a great degree. Electric traction, however, has made its way into this department of transport, as it has in nearly every other department of industry, and the electric locomotive is now nearly as familiar an object in the large shop as the electric crane.

For shop use the storage battery system has shown itself eminently adapted. Overhead wires are impracticable, except in very few instances, and since one of the great advantages of the industrial railway and electric locomotive lies in its service in transport between the various departments of an establishment, both within doors and without, no system can be acceptable which is not equally well adapted to both situations. For this reason the electric storage locomotive has been developed into a machine of great utility and efficiency in the handling of heavy material in and about the shop. Such a machine is capable of handling raw material, such as pig iron, sand, rough castings, etc., as well as finished parts, and completed products ready for shipment, the only requirement for this varied service being the provision of the different kinds of cars required for the purpose.

As in the case of the travelling crane, the economy of this mode of handling material is hardly appreciated until it has been tried. The visitor to the modern shop, if formerly acquainted with old-time methods, cannot fail to be surprised at the small number of men employed in other than productive work. The labouring gang is conspicuous by its absence. A man in a cab of an overhead crane, an operator on the platform of an electric locomotive—these, and a few men on the floor to handle slings, hooks and attachments, will be found doing all that formerly required a large body of men.

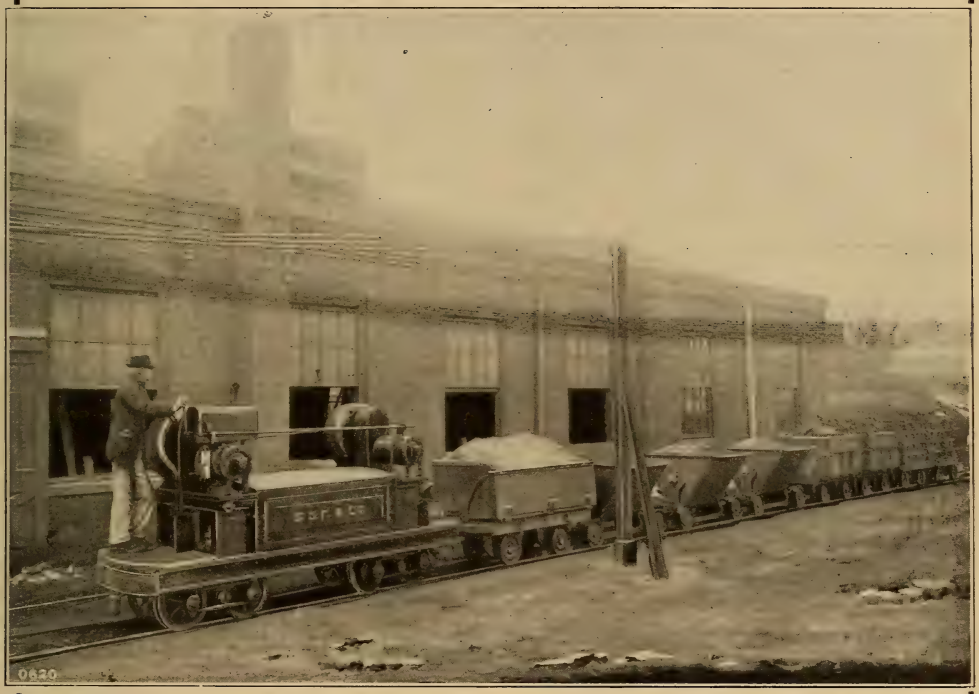
Apart from the immediate advantages attaching to the use of machinery in the place of human muscular effort, there are other considerations of importance. It is always desirable to avoid the employment of severe physical effort whenever possible, reserving the intelligence of men for the conduct of work requiring skill and judgment rather than brute force.

"HUNT"

Electric Storage Battery Locomotive

For Moving Heavy Material in Shops, Foundries, Manufacturing Establishments.

Highest Award at the World's Fair, 1904.



HAULING A TRAIN OF TIP, CHARGING AND FLAT TOP CARS, LOADED WITH SAND, PIG IRON AND MOLDS, FROM THE BINS TO THE FOUNDRY WITH AN ELECTRIC STORAGE BATTERY LOCOMOTIVE OF THE S. G. F. CO.

A manufacturing company some time ago decided to install in their foundry our "Industrial" Railway system and an Electric Storage Battery Locomotive, with a view to relieving the congestion of work which to them had become a serious problem. After the locomotive had been working some months, the Superintendent thought they really had but little use for it, as it was only in operation a few hours each day. Through carelessness it was run off the end of the track, and they were unable to use it for two days.

During that time it required 25 men each day to do the same work which the locomotive had been performing so efficiently and quietly that the superintendent had overlooked the importance of the work it was doing.

Some of the advantages of this Locomotive are:

Power is used only when the Locomotive is in operation.

One man only is needed to handle the locomotive and in yard work he lends a hand in loading and unloading the cars.

No fire risks on account of sparking at the contacts.

You are cordially invited to visit our Works, not only to see the locomotive at work, but to handle it yourself in doing its regular work.

Our Electric Locomotive Catalogue is illustrated and descriptive. Copy will be sent on request.

C. W. HUNT COMPANY

(Established 1872)

Main Office and Works:
WEST NEW BRIGHTON, N. Y.

New York City Office:
45 BROADWAY

The Control of Electrical Apparatus

ONE of the important advantages of electrical transmission of power lies in the opportunity which it offers for the prompt and reliable control of motion. So valuable and important is this element in an electrical installation that it has gradually become segregated from the manufacture of generators, motors and general electrical machinery, and become a special department of work, the products, in the form of controllers and similar appliances, being the results of the efforts of specialists in this particular field.

An important department of this large field lies in the design of controllers for use in connection with electrically-operated cranes and hoisting machinery. The extent of this department of work is continually increasing. So many large shops are now provided with electric current, either direct or alternating, that this flexible and convenient form of power transmission is used wherever possible.

Practically all travelling cranes are now operated electrically, while electric hoists, carried upon overhead tramrail, supplement the efficiency of the larger and more powerful apparatus.

The requirements for controllers for this service are peculiar and exacting. In the case of a travelling crane the motors which operate the travel of the bridge and the trolley perform their work under practically uniform conditions. The motor operating the hoisting function, however, is subjected to widely varying loads, dependent both upon the nature of the article to be lifted and upon the disposition to be made of it. That is to say, both the weight to be lifted and the velocity given to it are variables. In foundry service especially it is important that the movements of the crane be under perfect control. The handling of large flasks, containing important moulds, is a delicate operation, and excessive vibration, or any jerkiness of movement, might cause much injury and loss. For these reasons it is essential that controllers intended for hoist duty should be provided with proper resistance to insure correct speed regulation under light loads, a detail essential to satisfactory results with this class of machinery.

In certain locations controllers are required to be subjected to continuous duty, a condition which can readily be met when it is stipulated, but for which the ordinary apparatus is not adapted. The broad requirements of speed, current-carrying capacity and gradation of control can be met to almost any extent when such requirements are clearly stated and understood.

Under these circumstances it will be realized that the whole subject of electric-controller design is one forming a special department of electrical engineering, involving a wide experience, both in the electrical details and in the broad field of workshop conditions under which the devices are to be used. It is not too much to say that the success or failure of the application of electricity to such machines as cranes, hoists, elevators, and the like, is dependent to a great extent upon the correct design and performance of the controllers with which they are equipped.

Thus it will be seen that the engineer, planning an electric power installation, may design the general arrangement of the system, taking into account the actual operative conditions, and choosing the character of current, whether direct or alternating, according to local circumstances, and alloting the power according to the duty demanded. He may then place the data thus determined in the hands of concerns who devote their entire effort to the design of controllers, knowing that among the innumerable practical applications already made there will be found designs adapted to his requirements, and far more suited to the work than any devices which he might determine by his unaided judgment.

Manufacturing News

The New Recording Milli-Volt Meter and Shunt Ammeter

ELECTRICAL engineers have long felt the need for an accurate and sensitive recording milli-volt meter which is adapted to practical every-day service, as well as for laboratory tests. There has also been a demand for a recording ammeter of the shunt type which can be connected by leads to the main bus-bar. The shunt system is especially economical where heavy currents are to be indicated or recorded, as the instruments may be located at a considerable distance from the main current, thus saving great expense in carrying the main conductors to the point where the instrument is located. The recorders illustrated herewith have been designed to meet these particular demands.

The two most important fundamental features of these recorders are a sensitive electrical movement of special design made by the Weston Electrical Instrument Company, and a new recording system using a patented smoked chart so arranged that there is absolutely no friction between the recording arm and the chart.

These instruments are so sensitive that the recording arm will move over the whole scale for five millivolts or less, making it possible to accurately record one ten-thousandth of one volt. The graduations on the chart are evenly proportioned over the entire range, the same as the Weston ammeter, so that even though there is only a small current flowing, the readings may be as readily taken as if the current was the maximum that the instrument would record. This feature will be greatly appreciated, as there are many places where it is desired to install instruments for increasing future demands, and it is important that the records be perfectly clear, even though the loads are very light when the outfit is first installed.

The records are made on a novel semi-transparent smoked chart, which is periodically brought into momentary contact with the end of the recording arm by means of a special vibrating device. In this way a series of white dots are made on the smoked surface, and these form a continuous line, and a record is thus made without causing any friction between the moving arm and the chart. The rate of vibration of the chart is timed to suit the frequency and range of the variation in the current to be recorded. The usual period of vibration of the chart is once in ten seconds, but to obtain continuous lines where the fluctuations of the current are quite rapid, the vibrating attachment is made to operate twice every second. When the record is completed the chart is dipped in a simple fixative solution which makes the record permanent for filing.

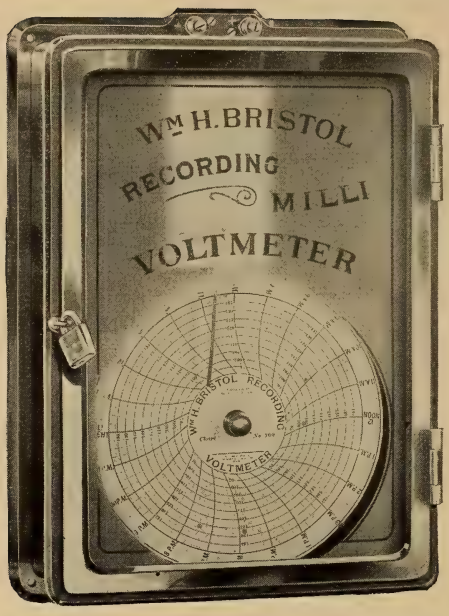


FIG. 1.—THE BRISTOL RECORDING MILLI-VOLTMETER

The recording milli-volt meter is shown in Fig. 1, and Fig. 2 is a reduced photographic facsimile of a chart taken from one of these instruments in connection with electrolysis surveys of underground structures which are being conducted by the Electrical Testing Laboratories, of New York City. The graduations of this chart are arbitrary. It was revolved once in twenty-four hours, and was vibrated once every ten seconds. The zero position of the recording arm was the middle of the scale, so that the record might be independent of the direction of the current, as in many cases the direction of the current changes from negative to positive during the day.

It is expected that, by using a number of these instruments operating simultaneously at different points, stray currents in water and gas mains, or in any underground structure, may be recorded, making it possible to discover the causes of trouble and how they may be eliminated.

The recording ammeter is shown in Fig. 3 connected to a standard Weston 10,000-ampere shunt, to which is also connected a Weston indicating station ammeter. This illustration shows that the recorder may be readily applied to any standard shunt which is already in service without disturbing the indicating instrument at the switchboard. As illustrated here, leads of almost any desired length may be used to connect the indicating and recording instruments to the shunt on the main bus-bar. It is even possible to have the recording ammeter located in the superintendent's office at a great distance from the shunt and the indicating instrument located on the switchboard convenient for the observation of the operator. Such combination outfits could be furnished as units, with leads of the proper lengths to suit the individual cases.

The recording shunt ammeter has been successfully applied for taking continuous records of the current on a large trolley system, where the fluctuations are very rapid and varied as much as 4,000 amperes several times in a minute. The charts for such work as this are made to revolve once in one hour and the vibrator operates twice in one second. For preliminary tests, the recorders are provided with special fast vibrators for the smoked chart and with a clock movement to revolve the

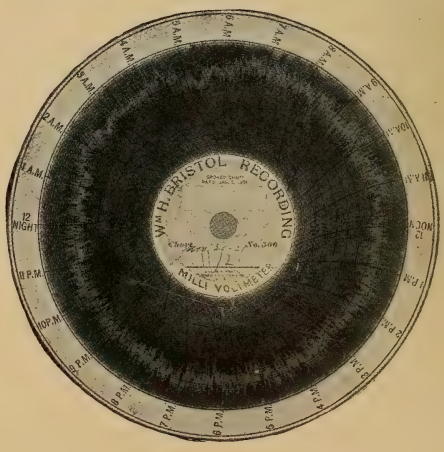


FIG. 2.—CHART FROM MILLI-VOLTMETER

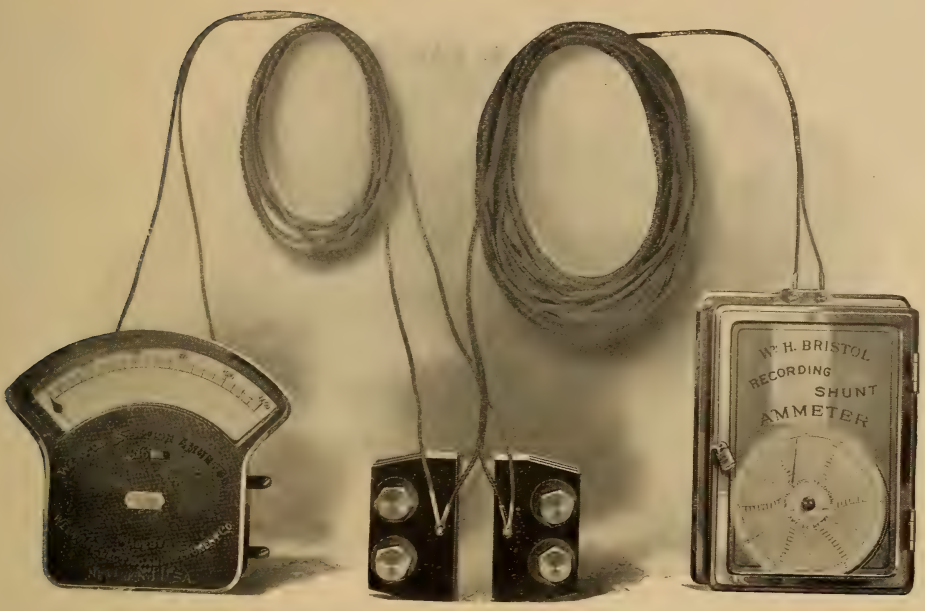


FIG. 3.—BRISTOL RECORDING AMMETER, WITH WESTON SHUNT AND WESTON INDICATING STATION AMMETER

chart once in one hour, but for continuous daily records the standard twenty-four-hour charts are recommended.

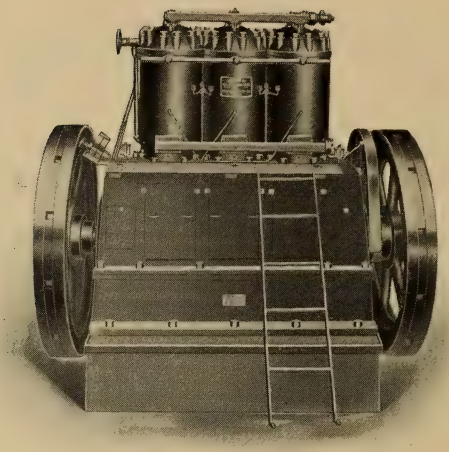
These instruments are manufactured by Wm. H. Bristol, 45 Vesey Street, New York City.

Well-Drilling Machinery

WILLIAMS BROS., Ithaca, N. Y., the well-known well-drilling machinery firm, have just published for gratuitous distribution a catalogue illustrating and describing over seventy styles and sizes of machines for drilling either deep or shallow wells in any kind of soil or rock. The drilling machines made by this company contain all the latest and best improvements, guaranteed to be strong, simple and durable, and are easily operated. For drilling wells for houses and farms, and in prospecting for coal, gas, oil, etc., they are without an equal. It will pay those who are about to start into the business of drilling wells, as well as those who already own well-drilling machinery, to write for a copy of this new catalogue.

Electric Locomotives

"THE Electric Locomotive in Heavy Passenger and Freight Work" is the title of Bulletin No. 4,537, recently issued by the General Electric Company, Schenectady, N. Y., in which is described a large number of present and proposed representative types of electric locomotives built by the company. Sketches are given of locomotives ranging from 17 to 150 tons for all classes of service, including mining, high-speed passenger, slow-speed freight, mountain-grade trunk lines, etc. Electrical and mechanical data are given, and characteristic curves for each locomotive shown. A short preface briefly describes the reasons for the growing demand of electric traction, and gives interesting facts regarding the construction and characteristics of the General Electric heavy traction motors and locomotives, with figures relative to the saving effected by the substitution of electric for steam traction in both passenger and freight work. Bound in a flexible brown cover, the publication forms a ready reference book.



THE NASH THREE-CYLINDER GAS ENGINE

The Nash Gas Engine

THE illustration shows the latest design of three-cylinder, vertical, self-contained Nash gas engine of 175 horse-power.

This engine has a number of valuable features, all tending toward simplicity and reliability of operation. Lubrication is effected by having the crank and shaft operating in a bath of oil, the crank case being readily accessible by doors. Snap doors are also provided, to enable the main bearings to be inspected while the engine is in operation. All the important bearings of the engine are supplied by force-feed lubricators.

It will thus be seen that the principal aim in the design of the Nash engine is reliability of operation.

The ignition is effected by magneto, this being free from any mechanism other than the electrical connections to the igniters, the simplicity of this important feature being a most desirable point.

The engines are adapted for the operation of electric lighting plants, water-works and similar service, and are arranged to use city gas, producer gas or natural gas, as local circumstances may indicate.

The Nash gas engine is built by the National Meter Company, 84 Chambers street, New York City.

Reinforced Concrete in Factory Construction

REINFORCED concrete has provided for the manufacturer an entirely new building material. Indestructible, economical and fireproof, it offers under most conditions features of advantage over every other type of construction. The development has naturally been greatest in the larger centres of population, but it is extending rapidly to the remoter districts and, indeed, wherever new buildings are contemplated.

This widespread interest demands an authoritative treatment, and the Atlas Portland Cement Company has embraced this opportunity to present to the manufacturer, and also to the architect and the engineer who are not concrete specialists, a brief treatise on reinforced concrete for factory construction, with a view of giving a comprehensive idea of the advantages and limitations of the material as adapted to the factory, and a demonstration of its value as illustrated in a variety of buildings in different localities.

The work has been prepared by Mr. Sanford E. Thompson, who is well qualified to treat the subject as an expert authority. The Atlas Portland Cement Company, occupying, as it does, a somewhat unique position

among cement manufacturers, with its wide reputation for a thoroughly uniform and satisfactory product, and its immense production—claimed to be greater in 1907 than that of any other four cement manufacturers in the world—commends the book to every one interested in the construction and use of factory buildings.

Allis-Chalmers Gas Engines

WITHIN the past year Allis-Chalmers Company has taken orders for thirty-six gas engines of 4,000 horse-power each, or an aggregate of 144,000 horse-power, twenty-five of which are to be installed as a part of the mammoth new plant now in course of construction by the Steel Corporation at Gary, Ind., seven for the Homestead plant of the Carnegie Steel Company, and four in the South Chicago works of the Illinois Steel Company.

It will require 2,300 cars to transport these machines from the works of the Milwaukee company to the different plants of the Steel Corporation, where they will be installed.

The wide use of gas engines by the United States Steel Corporation marks an important step in the progress of steel manufacture in this country, as they are designed to operate upon the hitherto "waste" gas developed by the blast furnaces, thus inaugurating an important economy in steel production.

The majority of the Allis-Chalmers gas engines on order will drive electric generators of standard Allis-Chalmers type, 25-cycle, three-phase. These machines are to be used for generating the necessary power to operate the heavy induction motor-driven rolls, the tilting and feed tables for the various passes, the hot saws, hot and cold pull-ups, transfer tables, strengthening machines and cold saws, and other auxiliary machinery of the mills which are now ordinarily operated by means of steam power.

In addition to the gas-engine-driven electrical units, orders have also been placed with the Allis-Chalmers Company for twelve gas-driven blowing engines. The Indiana Steel Company, Gary plant, will have eight blowing engines, and the Homestead plant of the Carnegie Steel Company has ordered the remaining four units. Each blowing engine has a capacity of 3,500 H. P., and will deliver 30,000 cubic feet of free air per minute against a pressure of 18 pounds per square inch, which is ordinarily the maximum. All of the gas-driven blowing engines purchased by the Steel Company's plants will be equipped with "Slick" type blowing tubes, the American patent rights covering which are owned by Allis-Chalmers Company.

In steel plants where steam-driven blowing engines have heretofore been using steam furnished by boilers utilizing waste gases from blast furnaces, it is ordinarily found that the amount of gas is at times not sufficient to supply the required power for this purpose only. But the same gas when used in gas engines not only furnishes sufficient gas for supplying all the air required by the furnaces, but also a considerable quantity over and above the requirements, which is used, as in the present instance, for driving electric generating units supplying sufficient power for the other uses common to the steel mill.

American Society of Mechanieal Engineers

THE next monthly meeting of the American Society of Mechanical Engineers will be held Tuesday evening, January 14, in Assembly Room No. 1 of the Engineering Societies Building, at 29 West Thirty-ninth street, New York.

The subject will be "Car Lighting," the presentation being made by Mr. R. N. Dixon, president of the Safety Car Heating & Lighting Company, and will treat of the general subject of light of trains, showing relative economies in the several systems, electric and gas.

The Mechanical Missionary

THE power-driven rock drill is a mechanical missionary, and one of prolific accomplishment. It is a doer of good in large measure, so that the works of the conscious, purposeful, professional, beneficent are belittled by comparison with it. The wealthiest man who ever lived could not have given to the world a tithe of what this thumping, punching and apparently rough-and-ready device has contributed. Its work is essentially the simplest that could be thought of, merely to perforate earth's cuticle in predetermined spots. Only to make the holes is all that is demanded, and no precision of either location or dimension is required. Yet this simple operation and the apparatus which has made it easy to do afford perhaps the most striking enforcement of the dictum that every cause is productive of more than one effect. In the case of the rock drill as a cause the effects of it are innumerable, and many of them reach far beyond our ken.

The first notable work of the rock drill was in the driving of the Hoosac tunnel, a task so hopeless before its advent that the time of the tunnel's completion was suggested by the Autocrat of the Breakfast Table as the end of all things and the period for the donning of our ascension robes. The tunnel was easily enough bored when the rock drill got at it, and the tunnels it has driven since and the open cuts are only to be measured by the thousands of miles.

But that was only the beginning, and only one of the many special lines of employment which the rock drill has made for itself. If it now has one specialty upon which it may pride itself more than another, and by reason of which all mankind are most indebted to it, the specialty is mining, the unlocking of the treasures of earth. Whether it is lead or silver or gold, or the vastly more valuable copper and coal and iron, these all it makes free to man to use as he will for every purpose that may be devised. The rock drill works to the greatest depths and has been the sole means of reaching the greatest depths below the surface, and it works equally well in the open to the limits of accessibility in the mountains. In its unearthing of treasure it goes to the remotest corners of the globe, so that the one special area in which it is most numerously employed to-day is not in the seats of civilization, ancient or modern, but in the farther corner of the dark and so long unknown continent. On the Rand, in South Africa, and not in the metropolis of either the Old or the New World, is where the rock drill is the most numerous and the busiest. And it goes not alone to the remote and hitherto inaccessible and uninhabitable regions where the mineral treasures are most likely to be stored. It is always in touch with the spirit of the age and draws after it all the agencies and the facilities of civilization and plants them everywhere to stay. It is banishing the savage from the earth. The railroads which lace the continents, and the canals from sea to sea, are the creations of the rock drill, and in the promotion of universal intercourse and mutual knowledge and a recognition and full appreciation of the common interests of the race it is foremost.

As illustrative of the diversity of effects which may follow the single cause it is to be remembered that the air compressor, as a machine of established manufacture, became so upon the demand of the original rock drill. For a long time the almost sole employment of the compressors, when first built in numbers and of respectable size and efficiency, was the driving of the rock drills which had called them into being, the field of their first activities being almost exclusively in mining and tunnel work. The supply of compressed air by the presence of these compressors being made easily attainable, the diversifying employments and the multitudinous variety of compressed air tools and appliances rapidly developed.

Manufacturing News

The Smokeless Combustion of Coal

IT is now generally understood that bituminous coal can be burned under steam boilers with the production of such a small amount of smoke as to remove altogether any objection to the use of such fuel even in large cities.

Among the various methods by which this effective combustion may be effected the so-called "under-feed" system possesses features of interest, since it removes, in great measure, the laborious work accompanying hand firing, employing mechanical power for the delivery of the fuel into the heart of the fire, and also because it includes the sound principle of feeding the fresh coal beneath the incandescent bed in the furnace, compelling the volatilized hydrocarbons to pass through the zone of complete combustion of incandescent coke in connection with a suitable proportion of air.

The Underfeed Stoker Company of America has recently issued some very handsome publications, illustrative of the manner in which this method of firing is effected by the Jones stoker, and among these publications is included the valuable address delivered before the International Association for the prevention of Smoke, by Paul M. Chamberlain, M. Am. Soc. M. E., upon the subject of boiler-room economy. Mr. Chamberlain shows very clearly how complete combustion is essential to maximum economy in the development of power from coal, and how the absence of smoke necessarily follows complete combustion.

Tests of boilers equipped with Jones underfeed stokers show excellent efficiency with boilers of various types, together with such thoroughness of combustion as clearly indicates the effectiveness of the apparatus.

American Steam Turbines in Japan

IN the development of Japan the progressive Japanese make it a point to purchase nothing but the most up-to-date material. The Japanese were among the very first to anticipate that the turbine engine was to be the foremost power producer of the age, and as a consequence a great many American turbine engines have been installed in that far-away country. A total of sixty-nine units, aggregating 60,000 horse-power capacity, of the Curtis type of turbo-generator, manufactured by the General Electric Company, of Schenectady, N. Y., have been installed in that country.

The sixty-nine machines are distributed as follows: Chita Cotton Mill, one 25-KW. unit; Fuji Cotton Mill, two 1,000-KW. unit; Hakata Electric Light Company, one 500-KW. and one 20-KW. units; Ichinomiya Cotton Mill, one 25-KW. unit; Imperial Steel Works, one 25-

KW. unit; Imperial Government Railway, one 35-KW. unit; Kawasaki Dockyard Company, Kobe, one 500-KW. unit; Kaneko Cotton Mill, Osaka, one 25-kw. unit; Kure Naval Dockyard, one 500-KW. unit; Maidzuru Naval Dockyard, one 300-KW. unit; Miye Cotton Mill, Osaka, two 25-KW. unit; Miike Mine, Omuta, three 1,000-KW. unit; Nisshin Cotton Mill, two 1,000-KW. unit; Nagoya Electric Light Company, two 500-KW. and one 25-KW. units; Oji Paper Company, Oji, one 500-KW. unit; Osaka Electric Light Company, four 500-KW. and two 1,000-KW. units; Osaka Military Arsenal, Osaka, eight 500-KW. unit; Osaka Municipal Railway, three 1,000-KW. unit; Sanyo Railway Company, one 25-KW. unit and one 15-KW. unit; Saseho Naval Dockyard, two 500-KW. unit; Senju Woollen Mill, one 150-KW. unit; Tokyo Electric Light Company, one 500-KW. unit; Tokyo Military Arsenal, Tokyo, four 500-KW. and two 500-KW. units; Tokyo Military Arsenal, Oji, three 500-KW. unit; Tokyo Railway Company, five 1,500-KW. unit; Tokyo Cotton Mill, three 1,000-KW. unit; Tenma Weaving Company, two 25-KW. unit; Yokohoma Union Electric Light Company, two 500-KW., one 1,000-KW. and one 1,000-KW. units.

Special Electric Controllers and Starting Devices for Battleship Equipment

A BOOKLET which should prove exceedingly useful to every one who sells electric motors or motor-driven machinery to the Navy Department has just been issued by the Cutler-Hammer Manufacturing Company, of Milwaukee, makers of electric controlling devices. This company for many years has made a special study of Navy Department requirements, and in the booklet just issued full descriptions, illustrations, dimension diagrams and shipping weights are given on starting panels, speed regulating panels, machine tool controllers, resistances, circuit breaker panels, etc. In the preface to the booklet in question attention is called to the fact that navy specifications preclude in nearly all instances the use of ordinary controlling panels, and, furthermore, that apparatus acceptable for use in navy yards will not always be acceptable if supplied for use on shipboard. How to select the proper piece of apparatus in each case is fully explained, and in addition to numerous illustrations of electric controlling appliances conforming to Bureau of Construction and Repair and Bureau of Equipment specifications, the booklet includes several views of battleships equipped with Cutler-Hammer control.

Notes

MR. WILLIAM D. ENNIS has been appointed as Professor of Mechanical Engineering in the Polytechnic Institute of Brooklyn, N. Y. Professor Ennis, who is most widely known through his contributions to the technical press, is a graduate of the Stevens Institute, and from 1901 was engineering adviser to various Rockefeller interests in the Northwest and elsewhere, including the American Linseed Company. Since 1905 he has been exclusively engaged on special power investigations for the American Locomotive Company.

American Society of Mechanical Engineers

NOTICE OF THE FEBRUARY MEETING

The first meeting of the gas power section of the American Society of Mechanical Engineers will be held Tuesday evening, February 11, in the Engineering Societies Building, at 29 West Thirty-ninth street, New York.

The subjects under discussion will be : "Experimental Gas Turbines in France" (with lantern slides), "A Simple Continuous Gas Calorimeter," "A Gas Engine and Producer Guarantee." Other subjects relating to the question of gas power will also be discussed.

Book News

Locomotive Performance. The Result of a Series of Researches Conducted by the Engineering Laboratory of Purdue University. By William F. M. Goss, M.S., D.E. Size, 6 by 9 inches. Pp. xvi, 439. New York: John Wiley & Sons; London: Chapman & Hall, Ltd. Price $5.

The work which has been done in the mechanical laboratory of Purdue University in connection with the locomotive-testing plant installed there since 1891, has attracted much attention, both in America and in Europe, and the results of various tests have been published and reviewed in the technical press and before professional engineering societies. The present volume contains a record of the most important of these results, together with other material not previously published, placing in permanent and convenient form the results of this pioneer locomotive-testing plant.

After a historical introduction, Professor Goss proceeds to discuss a typical example of locomotive performance, both as regards the boiler and the engines, taking into account changes in speed and cut-off, various rates of combustion, different methods of firing, etc. These chapters are followed by an examination of the effects of throttling, of the action of counterbalances, and of variations in valves and valve-gears. The book concludes with a discussion of the resistance of the atmosphere to the motion of trains, followed by a generalization concerning locomotive performance.

The great value of these discussions lies in the fact that they are based upon actual tests, in which all the data entering into the performance of the engine are capable of close measurement and determination. Before the initiation of these experiments there did not exist anywhere such a mass of reliable material; but to-day the locomotive designer has in his possession as accurate and reliable data as has the engineer who plans a stationary engine, and for this material he is undoubtedly indebted to Professor Goss and to Purdue University.

The testing plant of the Pennsylvania Railroad Company, originally installed at the St. Louis Exposition and since transferred to Altoona, is admittedly based upon the plan of Professor Goss, with the added advantage that it permits the application of the method to any engine which it may be desired to examine, so that the pioneer work in this direction, undertaken at Purdue, has led to a wide, practical extension of the system.

The book is well illustrated, with many diagrams and tables, and should be in the hands of every engineer connected with the design of locomotives or the conduction of railway motive power.

An Introduction to the Study of Electrical Engineering. By Henry H. Norris, M.E. Size, 6 by 9 inches. Pp. v, 404. New York: John Wiley & Sons; London: Chapman & Hall, Ltd. Price $2.50.

Professor Norris has here given us one of those works intended to lay a foundation upon which the student may thereafter build his own structure according to his environment. As he rightly says: "Observation and memory must supply the raw materials from which deductions are to be made."

The plan of the work is to take the everyday experience of the student as the basis of a general survey of electrical applications. Thus, the electric railway, the electric light, the telephone, etc., give every one contact with electric phenomena, from which a conception of the laws governing electricity may be deduced. It is interesting to note that Professor Norris admits that electrical engineering, once considered as a separate profession, is no longer such, but is becoming more and more a component part of general mechanical engineering.

Works of this sort are refreshing, in that they recognize the important fact that students should be taught general fundamental principles rather than a multitude of details. No man can predict the trend of the work of the student in his future career, but the fundamental laws upon which applied science is based will always be necessarily a part of his professional equipment, and a man who has thus a proper groundwork can readily work out his own salvation in time of need.

Highway Construction. A Practical Guide in Methods of Roadbuilding and the Development of Better Ways of Roadbuilding. By Austin T. Byrne, C.E., and Alfred E. Phillips, C.E., Ph.D. Size, 6½ by 9½ inches. Pp. viii, 136. Chicago: American School of Correspondence. Price $1.

The question of good roads is assuming more and more importance, in view of the wider interest which all elements of the community are taking in the matter. There is probably no more inefficient element in transport than a bad road, while a good road lends its efficiency to the animal, or the machine which expends its energy upon it.

The present volume, while primarily intended for use in connection with the work of the American School of Correspondence, is adapted for general reading and self-instruction, and should have a wide circulation and corresponding beneficial results.

Thoroughly practical in its arrangement, it starts out with an examination of the resistance to traction on roads under varying conditions, followed by a consideration of country roads, pavements for city streets, block, brick, wood and asphalt.

The important question of foundation is fully considered, a matter which is too often made subordinate to that of surfacing. The latter is the most obvious portion of a roadway, and yet is altogether secondary in value to that which lies beneath, and this fundamental element in good roads is given full attention.

The book is to be recommended as an entirely practical treatise upon a subject of present importance, and should have a far-reaching influence.

Engine-Room Chemistry. A Compend for the Engineer and Engineman. By Arthur H. Gill, S.B., Ph.D. Size, 5 by 7 inches. Pp. x, 198. New York: Hill Publishing Company. Price $1.

It is most encouraging to note that an elementary knowledge of chemistry is beginning to be considered desirable for the man in charge of the engine and boiler room, since it is a recognition of the fact that the generation of power by the combustion of coal is largely a chemical operation.

This little book discusses the nature of fuels, the chemistry of their combustion and the character of the products of that operation. The chemistry of water and its purification forms an important subject upon which the operating engineer should have at least some knowledge, while the composition and behaviour of lubricating oils are almost of equal importance.

While Professor Gill treats of these subjects somewhat after the manner of the pedagogue, he has made the

discussion clear and intelligible to men who may have had no preliminary knowledge of chemistry. The moderate size of the book prevents it from discouraging the beginner by any apparent voluminousness, and yet the essential features of the subject appear to be well covered. Especially to be commended are the words about "fake" fuel-saving compounds, and the like, and no engineer who has made himself familiar with the subject through the pages of this volume is likely to be deceived by any such nostrums.

A Treatise on Hydraulics. By William Cawthorne Unwin, LL.D., F.R.S. Size, 5½ by 6½ inches. Pp. xii, 327. London: Adam and Charles Black; New York: The Macmillan Company. Price $4.25.

The appearance of a new treatise by Professor Unwin upon a subject in which he has always been considered an authority, calls for especial attention. Since the early sixties of the last century he has been engaged in teaching and in the design of turbines and pumping machinery, and his article upon the subject, written in 1876 for the Encyclopædia Britannica, has been considered as authoritative ever since its appearance.

Professor Unwin accepts at once the fact that a strictly rational consideration of the subject of hydrodynamics would lead to results altogether at variance with the behaviour of actual fluids, since such treatment assumes the absence of viscosity. The working formulas and tables with which the engineer must deal, therefore, are based upon experimental researches of varying trustworthiness, covering a period of more than two centuries, and including a great variety of conditions. The real value of theoretical investigations of such a subject, therefore, consists in the reduction of this mass of experimental data to some sort of logical form.

Even when empirical formulas must be used, it is practical to investigate their limitations and prevent them from being misused, as well as to enable an intelligent choice of data and methods to be made for the special case under consideration.

After a review of the properties of fluids and the distribution of pressures, Professor Unwin proceeds to discuss the behaviour of water in motion, both uniform and varying. This is followed by an examination of discharges from orifices and flow over notches and weirs, these investigations naturally leading to a study of the flow of water in pipes, canals and streams. The book concludes with a valuable chapter upon the impact and reaction of fluids, followed by an appendix containing tables for use in connection with hydraulic computations.

Apart from the value which any treatise by Professor Unwin naturally possesses, the noteworthy characteristic of the work lies in the extent to which it includes the results of the latest researches in hydraulics. The most reliable data now available are to be found in the transactions of the principal professional engineering societies, and these have been most thoroughly considered in this book, so that it presents a digest of modern hydraulics of the utmost present and practical value to the working engineer, both civil and mechanical.

The Earth Taster

THE cheese and butter taster, which draws samples from the middle of a big cheese or of a tub of butter, is a necessary instrument of the grocer, both in the buying of his stock and in the convincing of his customers. There may have been a time when this taster was not known, and we can easily imagine the uncertainties which existed and the trickeries which were possible before its general adoption.

The function of the earth taster is strikingly analogous to that of the cheese taster. Beneath earth's surface is wealth unknown, and man is a constant and persistent buyer of the treasure, paying always for each successive acquisition more or less of labour, which is the established medium of exchange. The earth taster is, on the face of it, as necessary an instrument as could well be imagined, since the stores to be investigated before purchase are so diverse and so little to be predicted before the actual sample is secured.

Unless the material is sampled beforehand, immense labour values may be, and often have been, absolutely thrown away, because no valuables as sought have been secured in return. Many of the treasures which we seek in the earth are not immediately available and valuable when secured, but require much more labour to sift and sort out and concentrate before it can be determined whether they will yield an ultimate profit or not. Some will pay and some will not, and whether they will or not can usually be determined from the sample as well as from the labouriously and expensively procured mass. In the same neighbourhood the paying deposit may be very close to that which would yield no profit, and successive samplings, at comparatively infinitesimal cost, will enable the purchaser with his cash, which is labour in his hand, to discriminate and buy at the cheapest.

The labour-saver is the money-saver always, but the conventional and familar labour-saver is the one who saves at a time only percentages, often minute, of the labour expended upon the special operation. No other labour-saver but the earth sampler does its saving in totals by preventing labour from being employed at all in places where it would prove unprofitable. If we go fishing and catch nothing, that's a dead loss, of course; but if we bore with our earth taster and find nothing, that's the reverse, because we then have averted the losing employment of labour and all the paraphernalia for shaft-sinking, tunnel-driving and wholesale excavation. Much of the work of the earth taster would be thoughtlessly deprecated as unprofitable, since nothing of value is found by it when seeking, and if that were the constant and inevitable result secured it would be right to drop it; but instead its employment is constantly increasing, since it is in so many cases so far from failure and becomes the guide to treasure by the shortest and the cheapest route.

The core drill in its function of earth taster is typical of the modern economies in securing and working earth material, which material, as far as we have to do with it, is, of course, mostly rock. In mining and quarrying, as a whole, perhaps as much improvement in means and methods has developed as in any other line of human activity. In any case, to secure the valuables sought there is involved the handling of much material which is worse than worthless, and the taster, wisely used, enables the operator to avoid much of the latter while securing more of the former. The practical miner needs the taster proportionately much more than does the grocer or provision dealer.

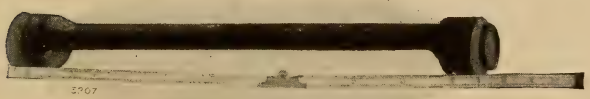
There is one inevitable suggestion in connection with the use of the earth taster. We are all joint owners of the earth, and the tasting of it by whoever and whatever should be a matter of permanent and accessible record for the benefit of all.

THE DAVIS **CALYX** DIAMOND-LESS

CORE DRILL

Core of Soft Coal 5" dia., extracted by "Calyx" Drill

These illustrations give some idea of the work of the "Calyx" drill. The cores shown were removed by standard machines without the use of diamonds. The materials range from sandstone and soft coal to rolled steel. Most of these cores are larger than any diamond drill could cut without a prohibitive cost for diamonds. The capacity of the "Calyx" drill is for cores from 1⅝ to 15 inches in diameter, from all reasonable depths to 6,000 feet.



Core of a 20-inch "I" beam extracted by the "Calyx" Drill when making foundation soundings in New York City

The cost of a "Calyx" core hole of a size adapted to ordinary contract sounding or mine prospecting is $0.75 to $2.00 per foot. Compare this with the cost of a prospect shaft—$10.00 to $30.00 per foot—and the saving by the use of the "Calyx" drill becomes apparent. Catalog 91.

AIR COMPRESSORS ROCK DRILLS
CHANNELERS PNEUMATIC TOOLS
PNEUMATIC PUMPING SYSTEMS

INGERSOLL-RAND CO.

11 Broadway, NEW YORK

Chicago	St. Louis	Philadelphia	El Paso
Cleveland	Pittsburg	Birmingham	Boston
Butte	Houghton	San Francisco	Seattle
Denver	Salt Lake	Los Angeles	Montreal

V32

Shop Railways

IN another place in this magazine there are discussed some recent machine tools adapted to the manufacture of gas engines and similar machines. In connection with such work there must also be considered the rapid and convenient handling of the material, both in the rough and finished condition.

In the modern machine shop the work should practically flow through the works with as little obstruction to its forward progress as possible. Raw material, delivered in the stock room, must be arranged so that it can be stored with a minimum of effort, and sent on through the shop on requisition without delay and without requiring the maintenance of a force of labourers. This means the provision of both indoor and outdoor transport, best supplied by a system of shop railways, with cars, switches, turnouts and all the accompanying conveniences.

Such a system, however, is of minor value if confined only to the stock department, and the progress of the machined parts through the different operative departments demands as much consideration as the movement of the machined surfaces in the tools. It is of little avail to install high-speed steel and speed up the shafting and machine tools if the time thus gained is to be wasted in the handling of the finished parts, and the same attention must be given to the arrival and departure of the different portions of the product under construction as to the handling in the lathe or on the planer. This principle holds good through the erecting department to the finished stores department, so that, as a well-known engine-builder once said, a shop should be so arranged that pig-iron comes in at one end and finished engines flow out at the other.

It is to facilitate just such a flow that the industrial railway comes in, and it has rightly been said that, when viewed in this light, it is properly considered as a machine, just as fully as any other tool in the shop.

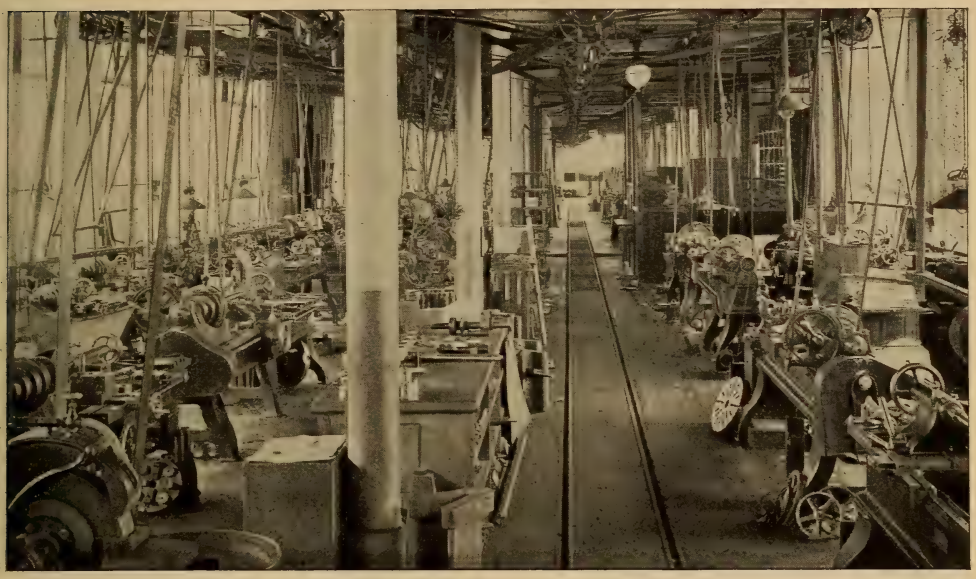
In the great majority of cases such a railway is operated by manual power with satisfactory results, since the use of roller bearings and standard curves and flanged wheels reduce the effort required to a minimum. In large shops, however, or in locations in which widely separated buildings occur, the system is especially adapted to electric traction, a special design of storage-battery electric locomotive being available.

The whole tendency in this department of shop equipment, as elsewhere, is to reduce the labour cost of the product, and to restrict human effort to those portions of the work involving the exercise of judgment and discretion. The ordinary labourer can, in most instances, be replaced to great advantage by some mechanical device, both as regards the satisfactory manner in which the work is done and the actual money saving involved. This latter item is not always properly considered. Labourers naturally receive lower wages than skilled machinists, but the wages of a boy, at fifty cents a day, amounts to $150 per year, or 10 per cent. interest on an investment of $1,500, so that the first cost of any labour-saving installation should be considered in connection with the actual capitalization of the money saved.

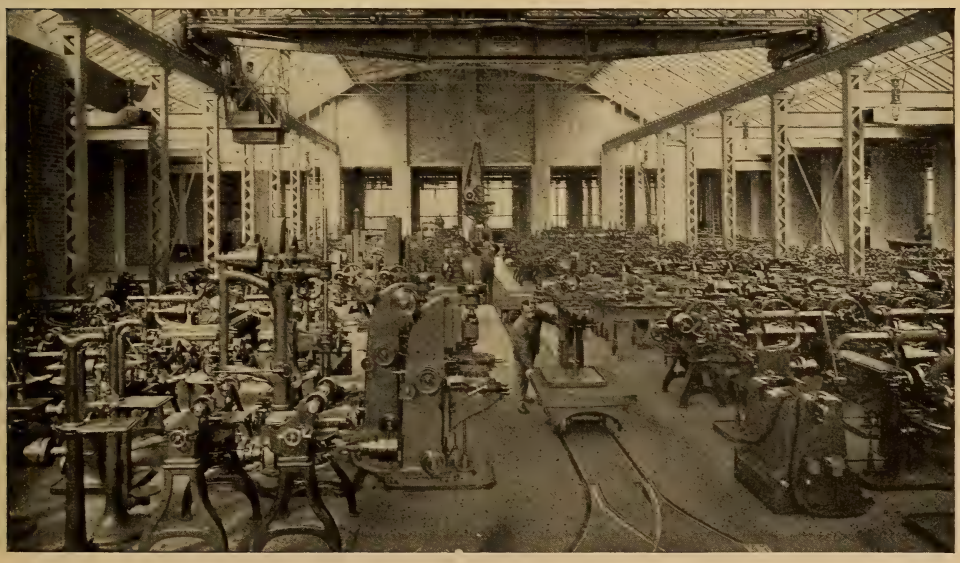
It is beginning to be realized that efficient shop management involves the perfection of a number of links in a chain of operations, each one of which is essential to the success of the whole. The failure of any portion of the scheme carries with it not only the conduct of the department to which it belongs, but holds up efficiency elsewhere, often in a greater proportion than is directly apparent. Of all such shop details the question of efficient transport is one of the most important, and any defect in this portion of the service may mar the whole of an otherwise admirable equipment.

C. W. HUNT COMPANY, West New Brighton, N. Y.

"Industrial" Railway (21½ in. gauge) in Machine Shops
(TRADE MARK)



"INDUSTRIAL" RAILWAY IN A TURNING SHOP ENABLES MATERIAL TO BE HANDLED WITH EASE AND RAPIDITY.



WITH AN "INDUSTRIAL" RAILWAY STOCK IS EASILY HANDLED FOR SHIPMENT.

The great saving **in ground space** by the use of a narrow gauge railway and flat top cars as compared with the standard 4 feet 8½ inch gauge, and the better utilization of floor space, is of more value than the whole cost of installing the "Industrial Railway." It will pay you to investigate this system Our Catalogue No. 0511 contains full particulars. Send for a copy.

Chain Blocks

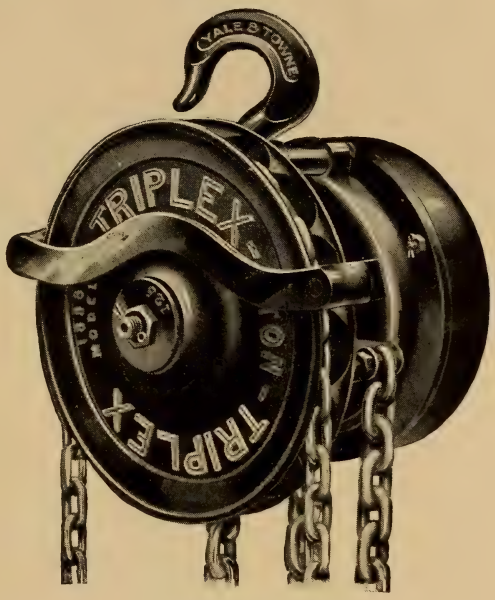
UNTIL about twenty years ago the appliances in general use for general hoisting purposes included the ordinary rope and tackle block, the Weston differential chain block, and a few chain blocks of the screw or worm and worm-wheel variety. When something better was required it was necessary to install some more bulky and expensive apparatus, involving a winch or winding drum, with its inconveniences and lack of portability. The rope hoist has always had its limitations when used for hand power directly applied, besides having the serious defect of inability to support the load. The differential block, however, achieved its great success because of its extreme simplicity, together with the fact that it did sustain the load at any point without any special attachment for the purpose. The measure of success which this simple, yet fundamental, invention achieved, may be realized when it is understood that the same patterns are used for its manufacture which were originally employed, no change whatever having been found necessary in the course of more than thirty years.

The self-sustaining feature of the differential block is well known to be attained at the expense of its mechanical efficiency. The internal resistance of the block is slightly greater than the external resistance, due to the load, and hence the descent of the weight must be assisted by pulling on the chain. This means that the machine has necessarily a mechanical efficiency of less than 50 per cent. For many purposes, especially when the hoist is used at infrequent intervals, this is a minor consideration, in comparison with the requirements of simplicity, convenience and moderate cost. When, however, it was thought necessary to meet the requirements for a chain-block hoist which should have a higher mechanical efficiency, and yet sustain the load at any point, the fundamental principle upon which such a device must be based became evident: the sustaining resistance must act only against the lowering action, and not oppose the effort of the operator when hoisting.

Upon this principle the so-called triplex block was designed many years ago by the same ingenious inventor who originated the differential block, and upon this principle every form of chain hoist of high efficiency must be designed. In the case of the triplex block a mechanical efficiency of practically 80 per cent. has been attained in hoisting, and this standard has been the aim of every subsequent design of chain block.

There is something more than mere mechanical efficiency, however, which enters into the design of a chain block. It must include a proper distribution of pressures amongst the various members of the gear train, a proper provision against unequal wear, and must cover the elements which conduce to efficiency in its use in the shop and elsewhere at all times. That these features were also included in the original triplex block appears from the fact that, with slight modifications only, it remains practically the same in design and construction as when it was first placed before the public.

It is results such as these which indicate the advantages of scientific skill and training in the design of mechanical appliances, as compared with the cut-and-try methods formerly supposed to be essential in the development of every invention, and still too often used, even when more correct methods are readily available. There is no royal road to invention, any more than in other departments of original work; but when a new idea is clearly conceived in the mind of an inventor it is nearly always possible to bring to the completion of the design the service of the fundamental principles of mechanics and the allied departments of applied science to an extent which will enable the highest degree of commercial success to be attained.



The Triplex Block

OUR Chain Blocks are made in four kinds and twenty sizes for every hoisting need:

Triplex, the best ***hand*** hoist; greatest ease, safety and speed. Capacity ½ to 20 tons.

Duplex, for ease and handiness. Capacity ½ to 10 tons.

Differential, the cheapest reliable chain block. Capacity ⅛ to 3 tons.

Y. & T. Electric, the best ***power*** hoist for rapid work. Capacity 1 to 16 tons.

We have a carefully illustrated catalogue showing them in use under various conditions. Let us send it to you.

The Yale & Towne Mfg. Co.

9 Murray Street, New York

Automatic Starting Devices and Remote Control of Electric Motors

TO users of electric power few devices employed in connection with motors are so interesting as the "self-starter." The construction and operation of the solenoid, which is a characteristic feature of these automatic motor starters, are doubtless familiar to most readers of this magazine; but unless one has been able to keep in close touch with the development of electrical apparatus in recent years, he is likely to be astonished at the results accomplished by this little coil of wire which, when energized by the passage of current through it, sucks up its plunger (or core), thus closing the circuit to the motor.

The travel of the plunger itself seldom exceeds a few inches, but this slight movement is sufficient to enable the self-starter to cut one step of resistance after another out of circuit, bringing the motor smoothly up to full speed. A dash-pot is sometimes combined with the starter arm operated by the solenoid for the purpose of prolonging the period of acceleration and thus obtaining the gradual increase in speed so vital to the satisfactory operation of electric motors.

In some plants automatic motor starters are installed solely for the purpose of preventing careless employees from starting up the motors too suddenly, but the value of the self-starter consists chiefly in the fact that when combined with suitable energizing devices, such as float switches, pressure regulators, limit switches, or even a push-button switch, it dispenses altogether with the need of employing some one to start and stop the motor at the proper time, or else enables the one charged with this duty to control the motor from a distance.

A good example of the advantage of remote control is found in mining work where (in mines employing manually-operated starting boxes) it is oftentimes necessary to send a man down the shaft to start a motor. In mines where self-starters are installed every motor can be controlled by switches located in the power house or at any other convenient point.

In connection with electrically-operated elevators, hoists, etc., the self-starter insures a smooth start and gradual acceleration to full speed, since by means of the dash-pot referred to the starting period is predetermined and is not affected by carelessness on the part of the operator.

In connection with motor-driven pumps and air compressors the self-starter finds one of its widest fields of usefulness. By means of a switch operated by a copper float in the tank, the circuit to the motor is automatically opened and closed through the self-starter whenever the water in the tank reaches a predetermined high or low level. The same device may be used in sump pits or, indeed, wherever there is sufficient change in water level to operate a float switch.

In compression tank systems, and when used with air compressors, a pressure gauge is substituted for the float switch, the circuit being made and broken as the needle, or indicator, moves back and forth between two fixed points.

Aside from the uses above indicated, the self-starter is widely employed in solving special problems involving electric control. One of the most interesting installations of this sort is a remote system of control designed and built by the Cutler-Hammer Manufacturing Company, of Milwaukee, for the Milwaukee Coke & Gas Company. Here self-starters are installed with the motors operating the conveyors that carry the coal from the various bins to the delivery wagons. A pilot switchboard located in the delivery office enables the manager to keep the loading of various grades of coal literally "under his thumb."

Manufacturing News

The Philadelphia Bourse.

IT is well known that the exhibition at the Philadelphia Bourse is a great centre where a large variety of machinery is always on display.

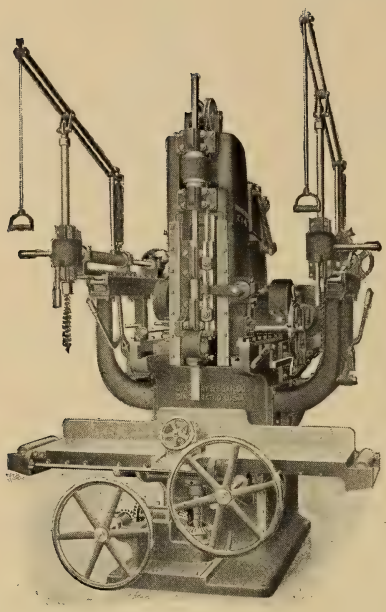
For this reason applications for space are continually being made, and some of the latest additions will be found of interest.

The New York Revolving Portable Elevator Co. of Jersey City, N. J., have rented space to exhibit their Portable Elevator. The elevator they have on exhibition embraces features of a pivot crane, in that it revolves and it is portable. It is provided with a platform to convey the goods, and the same can be raised to the height desired and then discharged with no difficulty. It is a decidedly useful machine and we bespeak for it great success, by reason of the comments we hear made in its favour. Mr. W. N. Dumbrill is their representative.

The Lindsay Hyde Co. of Philadelphia have become the licensees of the National Freezing Machine Co., with office in the exhibition department. The above company are in every way qualified to manufacture and fill the many orders that are being received for this refrigerator. It is also the purpose of The Lindsay Hyde Co. to make an elaborate display of the same, by having a complete installation in the exhibition, where it may be seen and demonstrated.

The Alamo Manufacturing Co., Hillsdale, Mich., have recently placed a line of their products in the Philadelphia Bourse Exhibition as an exhibit and for sale. They are well-known makers of gas, gasolene and distillate engines, portable and stationary, for factories; electric lighting, mining hoists, pumping and contractors' outfits. Mr. C. Pfau is their representative, who can be reached either by mail or by personal call. Mr. Pfau is greatly encouraged with his success by having a display in the Bourse Exhibition since the first of January, 1908.

The W. F. Killion Co. of Philadelphia have taken space to exhibit the Barber gas and gasolene marine engines, launch and yacht brass and bronze supplies. They are making a very elaborate display of the line of goods represented by them. The W. F. Killion Co. feel greatly encouraged with the results of sales made since they placed their goods on exhibition.



FAY & EGAN CAR MORTISER

A Car Mortiser Designed for Heavy Work.

THE latest car mortiser built by the J. A. Fay & Egan Co., 226-246 W. Front street, Cincinnati, Ohio, is designed for heavy work in both car and bridge construction, and is made with one, two or no-auxiliary boring attachments. It has a capacity for mortises from ½ inch to 3 inches square, and up to 6 inches deep; or, by reversing timbers, 12 inches deep. The frame is a single-cored casting with wide base of immense weight. The housing is securely gibbed to the frame, with provision for taking up wear, and moves transversely on frictionless rollers by hand-wheel, and can be securely locked in any position desired. The chisel ram is gibbed to the housing, and has a vertical travel of 18 inches. The auger spindle is driven at the proper speed by a belt with take-up, so that the strain is constant, regardless of the position of the housing. The reciprocating motion of the chisel ram is produced by a pinion in a rack, operated by friction pulleys, giving a constant and positive drive. The table is made either stationary or traveling. The stationary table is 6 feet 6 inches long, and is provided with stops to regulate the length of mortise. It is operated by hand-wheel, rack and pinion, and can be raised and lowered by hand. The traveling table can be furnished any length desired. It is made of steel I-beams, has automatic feed, under instant control of the operator, and is provided with adjustable stops for regulating the distance between mortises. The countershaft is self-contained in the base of the machine, convenient for direct connection of motor drive. It has tight and loose pulleys, 18 inches by 8½ inches face, and should make 840 R. P. M. The auxiliary boring attachments angle 30 degrees in either direction. The two spindles have a vertical stroke of 18 inches and a lateral adjustment of 18 inches, and are driven by independent countershafts, having tight and loose pulleys, 10 inches by 4½ inches face, and should make 750 R. P. M.

An Improved Hoisting Drum.

CONTRACTORS especially will be interested in a new fourteen-page illustrated booklet on the "Two in One" Hoisting Drum which has just been received from The Hayward Company, 97 Cedar street, New York City.

An attractive illustration on the cover gives a good idea of this ingenious device, the booklet itself treating largely of its application to the various types of machinery capable of operating automatic buckets, a number of which are shown.

As the name implies, the "Two in One" drum consists of two drums mounted on the same bed plate, and acting as one drum.

It is not connected to the engine by gears or sprocket chains, so the necessity of changing the engine with which it is to be used in any way is eliminated.

A contractor who has several single-drum hoisting engines, wishes to use double-chain automatic buckets, or should he have double-drum engines and, in addition to operating the buckets, wishes to raise and lower the booms,—the all important question is an additional drum, which in all probability he will order from the engine manufacturer. To connect this drum, the engine should be mounted on wooden skids to receive the pedestals which carry the new drum shaft. These pedestals have then to be bolted to the skids and the shaft lined up so that the gears mesh properly.

These changes must often be made miles away from a machine shop, and are expensive, in time and labour.

The "Two in One" Hoisting Drum does away with these alterations, and requires no more intelligence to put in operation than the placing of a hoisting engine and leading the lines to a derrick.

Its cost is determined by the size and style of bucket to be used, but in any event is less than an additional drum.

Copies of the new booklet will be sent by the Hayward Company to engineers, contractors and others, and we are sure they will find it of interest.

Hydro-Electric Plant for Tokio, Japan.

THE first 60,000-volt hydro-electric plant in Japan has just been put into service with signal success after having passed the rigid inspection which is required by the Japanese Government of all electrical installations. Power is obtained by impounding the Ugigawa River, a narrow and swift, but deep river such as is often found in the mountainous portions of the Flowery Kingdom. The normal capacity of the main station is 18,000 KW., and is furnished by six 3,000 KW., 50-cycle, 6,600-volt water-wheel driven alternators.

The generator voltage is stepped up to the line voltage of 60,000 volts, through three banks of three each single-phase water-cooled 2,000 KW. transformers, at which potential it is transmitted 25 miles to the Waseda substation, just outside the city of Tokio. In this main substation water-cooled transformers of 1,800 KW. each step down the line voltage to 11,000 volts, at which potential it is transmitted underground through lead-armoured cables to eleven distributing substations, situated in various parts of the city.

In each of these smaller substations oil-cooled transformers of 250 KW. capacity step the voltage down to 2,000 volts, the line potential of the city circuits. The territory immediately surrounding the Waseda substation is also fed with low voltage current for light and power purposes.

The entire transformer, regulating and controlling equipment, consisting of eighteen water-cooled and fifty-four oil-cooled transformers, eighty-one single-phase induction feeder regulators and 149 switchboard panels, was furnished by the General Electric Company, as was also the lead-armoured cable.

American Society of Mechanical Engineers.

THE March meeting of the American Society of Mechanical Engineers will be held on Tuesday evening, March 10, at 8.15 o'clock in the Engineering Societies' building.

The meeting will be addressed by Dr. Charles P. Steinmetz, member, A. S. M. E., past president, A. I. E. E., and professor of electrical engineering, Union University, Schenectady; the subject being, "The Steam Path of the Steam Turbine."

These monthly meetings are forming an important part in the activities of the society, and the attendance has been most gratifying. The February meeting, devoted to the work of the Gas Power Section, was especially well attended.

Spiral Riveted Pipe.

THE American Spiral Pipe Works of Chicago has issued a pamphlet devoted to the applications of Taylor's spiral riveted pipe in various departments of engineering work. This pipe has the advantage of lightness and strength, accompanied with moderate cost and a great variety of practical applications. As an example of the great resistance given to the pipe by the reinforcement due to the overlapping spiral seam, data are given concerning tests of a piece of 12-inch spiral riveted pipe, which withstood a hydraulic pressure of 650 pounds per square inch, bulging between the seams without giving way, although the pressure was more than that theoretically required to burst a seamless tube of the same dimensions.

In addition to the enormous bursting resistance of spiral riveted pipe, it has exceptional strength against collapsing under vacuum or heavy external pressure. The construction also enables it to resist bending under transverse loads, a matter often of importance in spanning spaces between supports.

The pamphlet contains numerous illustrations of spiral pipe as used for pipe lines, exhaust pipe, and other purposes, together with details of joints for connecting sections in different kinds of work.

The Sirocco Engineering Company.

THE principle of increased rotative speed as the proper means for increasing the power and capacity of machinery has met with numerous applications during the past decade. By increasing its rotative speed, the heavy gas or gasoline engine was converted into the powerful and light-weight motor, which made the automobile possible, and which is the principal factor in the coming solution of the problem of mechanical flight. The development of the steam turbine is well known, and in many departments of industry similar examples might be cited.

A noteworthy instance of the manner in which increased capacity might be derived from increased rotative speed, accompanied with such modifications in design as the conditions required, is seen in the development of the Sirocco fan blower. This machine, invented by Mr. Davidson, of Belfast, Ireland, includes the use of a special form of runner, with large axial openings and a number of small blades, the whole bearing much the same relation to the older types of blowers as the small, high-power turbine water-wheel does to the old-fashioned overshot wheel. The results of the development of this invention have been a reduction of about one-third in weight, and of one-half in space occupied, together with an economy of 10 to 20 per cent. in power.

During the few years in which the Sirocco blower has been on the market, from the original works in Belfast, it has been adopted by the British army and navy, by the Cunard, White Star, Hamburg-American, and other steamship lines, besides coming into general use in mines, power houses, schools, shops, factories, and other buildings.

The demand for the Sirocco blower in America has resulted in the formation of the Sirocco Engineering Company, with offices in New York City, at No. 138 Cedar street, and works at Troy, N. Y. This American company controls the business for the United States, with export privileges throughout Canada, Mexico, Central and South America, and Japan.

Canadian Rail Making

THE Canadian Pacific Railway has placed an order with the Lake Superior Corporation for 40,000 tons of 85-pound steel rails. Work has been commenced on this order by the Algoma Steel Company, Ltd., at Sault Ste. Marie.

Conveying Machinery.

The Robins New Conveyor Company, which has been recently incorporated, will be operated under the management of Thomas Robins, who founded the Robins Conveying Belt Company in 1896, and was president of that concern until March, 1907, when its management passed into other hands.

The position of chief engineer in the new company is filled by Mr. C. Kemble Baldwin, who has served in the Robins Conveying Belt Company in the same capacity for the last seven years. The offices of the company are at 38 Wall street, New York, and 1240 Old Colony building, Chicago.

Centrifugal Air Compressors for Industrial Air Blast and Exhauster Service.

LOW-PRESSURE air compressors rated from .88 pound to 4 pounds per square inch, and from capacities of 750 to 10,000 cubic feet of free air per minute, are included in the line of centrifugal air compressors, which have been developed by the General Electric Company, Schenectady, N. Y., and is described in Bulletin No. 4564. These machines are similar to the well-known centrifugal pump in both appearance and operation, and consist essentially of a rotating impeller surrounded by a suitable casing with an intake opening at the centre and a discharge opening at the circumference. The efficiency of apparatus of this character depends largely upon the design of the impeller and casing, and the present General Electric practice is based on a series of exhaustive experiments which have been carried out during the past few years. Compressor sets are furnished driven by Curtis steam turbines, direct-current motors and induction motors. Among the industrial applications are mentioned compressors used in foundry cupola service, for gas furnace service where a constant pressure is maintained, and for exhauster service in sulphite pulp mills, chemical works, etc., where a small degree of vacuum is required. They can also be used for the ventilation of deep mine shafts, copper smelting industries, kilns, glass and bottle works and filtration and purification plants. Some of the principal advantages of centrifugal compressors given in the Bulletin are low maintenance and repair, high efficiency and economy in operation, and floor space.

Tidal Power Development.

A NUMBER of plans have been made to develop the power of the tides, but in most cases these have failed of commercial success. The increasing importance of natural sources of power, however, is causing the subject to attract renewed interest, and a project is now well advanced to harness the power of the tides on the coast of Maine near the city of Portland.

Alfred S. Black, of Portland, Me., and his associates have bonded land on either side of Bacq Bay, in Portland, where it is anticipated a tidal power plant will be located, capable of developing at least 25,000 horsepower, or enough to run all the electric cars, lights and engines in the city. Associated with Mr. Black in the developing of these tidal power stations are William O. Webber, of Boston, hydraulic engineer; E. B. McAllister and F. Ernest Holman, of Rockland. Mr. Black says: "We shall commence the erection of our first power station at South Thomaston, four miles from Rockland, next spring, the plans for same being now completed, and the land and rights secured. We shall furnish power to Rockland, four miles away; to the Rockland & Rockport Lime Company for use in the lime quarries, and to the Thomaston & Camden Street Railroad."

THE LATEST CATALOGUES

Pumps.

A. S. Cameron Steam Pump Works, New York, N. Y.—A very complete catalogue of the direct-acting steam pumps built by the Cameron Company, containing valuable data and information for engineers. The simple valve-gear of the Cameron pump is illustrated in detail, while varieties of pumps for general service, boiler feeding, mine service, shaft sinking, etc., are illustrated, with tables of dimensions, weights and capacities. The data appended include tables of areas, pressures, frictional resistances to the flow of water, and other useful information, the whole forming a desirable collection of material for reference in connection with the movement of water.

Lathes.

Rivett Lathe Manufacturing Co., Boston, Mass.—Illustrated catalogue of precision lathes, milling machines and grinders, adapted for tool making and special work of moderate dimensions, requiring a high degree of accuracy. The illustrations and information of the grinding machines arranged to be operated at speeds up to 100,000 revolutions per minute, are of especial interest, as are also the structural details of the lathes and their attachments. These machines are especially suitable for electricians, modelmakers, tool-room work, and similar service.

Niles - Bement - Pond Company, New York, N. Y.—Special pamphlet illustrating the Pond Rigid Turret Lathe, a machine particularly adapted to such work as gear blanks, flywheels, gas-engine cylinders, etc., and designed to increase the output from 50 to 150 per cent. over ordinary engine-lathe methods on such work. This machine is built in two sizes, 21 and 28 inch, and is made especially heavy and rigid in order to stand the high duty for which it is intended. All the operative details of the tool are shown by reproductions of photographs, while drawings of a variety of work to which it is adapted are appended.

Machine Tools.

Potter & Johnston, Pawtucket, R. I.—Catalogue No. 12, devoted to the illustration of automatic chucking and turning machines, and universal shapers. Detailed descriptions of the machines are given, together with information showing the extent to which duplicate parts in iron, bronze, or steel may be rapidly and economically machined. A single workman may operate groups of two to six machines, enabling the output of automobile parts, gas-engine work, and similar products to be greatly increased at marked reduction in cost. In addition to these automatic machines there are shown in the catalogue two sizes of universal shaping machines, these being fitted with power feeds, automatic stops, graduated collars, and auxiliary tilting side for compound angles.

Gould & Eberhardt, Newark, N. J.—Special catalogue of High-Duty Shapers and Attachments. These machines are built in 14, 16, 20, 24, and 34 inch sizes, and are designed of exceptional strength and rigidity for use with modern high-speed steels and the heavy service demanded by their capabilities. Eight changes of speed are provided for every change of stroke, and the length of stroke is controlled with a high degree of precision. Detailed specifications, with illustrations, are given of the various sizes, together with descriptions of various attachments for use with these tools. The application of electric driving to these shapers is shown as arranged for variable-speed or constant-speed motors, the former including special clutch and brake attachment, and the latter illustrating the gear-box arrangement for speed changes.

Machine Tools.

LANDIS TOOL COMPANY, Waynesboro, Pa.—Illustrated pamphlet devoted to the Landis Grinding Machines and the correct methods of using them. This is a valuable work of instruction in the methods of correct grinding as applied to the production of cylindrical surfaces on spindles, cranks, internal work, and special parts, and forms a most useful reference book for the machinist and tool maker.

Steam Engines.

LAWRENCE MACHINE CO., Lawrence, Mass.—Bulletin No. 14, illustrating vertical simple and compound engines, designed for direct-connection to centrifugal pumps, and adapted also for hard and continuous general service, such as electric lighting and the like. Very complete tables are given showing the power developed by these engines at various speeds and pressures; the sizes of the simple engines ranging from 4 by 4 inches up to 16 by 16 inches, and the compound engines from 5-10-6 inches, to 20-40-24 inches.

Centrifugal Pumps.

LAWRENCE MACHINE CO., Lawrence, Mass.—Bulletin No. 15, devoted to turbine and electrically driven pumps for high-duty fire service and similar work. Pumps of capacities from 30 to 3,000 gallons per minute are listed, with data of powering, weights, and dimensions.

Gearing.

THE LONG ARM SYSTEM CO., Cleveland, Ohio.—Bulletin No. 25, describing the "Long-Arm" automatic attachment for use with milling machines for the purpose of chamfering or rounding the ends of gear teeth. The attachment is a convenient device for finishing the ends of gear teeth automatically, and especially adapted for the teeth of transmission gears for automobiles and for the sliding gears used in the feed mechanism of machine tools. It is designed to be attached to the table of the milling machine, the cutter being driven by the spindle of the machine, while the automatic movements are separately driven. Complete instructions are given for attaching the apparatus to a milling machine, and the device will doubtless find a place in many shops.

Foundations.

THE FOUNDATION COMPANY, New York, N. Y.—Illustrated catalogue devoted to the subject of concrete-pile foundations as constructed upon the Simplex system, the concrete pile being made in a cylindrical form previously driven into the ground, and subsequently withdrawn. Numerous illustrations are given of important foundations constructed upon this system, its effectiveness in difficult ground. The applicability of the system to piles of plain and of reinforced concrete is shown, as well as the composite arrangement of wood and concrete for very deep work.

Time Recording.

THE CALCULAGRAPH COMPANY, New York, N. Y.—A review of the operation of the calculagraph in the works of the Gorham Manufacturing Company, written by Mr. R. W. Higgins, and showing the value of machines for recording the actual working time of operatives in the determination and distribution of costs. A valuable treatise on shop accounting and the importance of mechanical appliances in such work.

Forging.

THE BILLINGS & SPENCER CO., Hartford, Conn.—Catalogues of improved drop hammers and attachments, together with illustrations of trimming presses, furnaces, etc. A number of products of the drop-forging press are shown, including forgings of automobile parts and similar work.

A Typical Invention

THE initial act in the invention of the electric air drill, the first recognition or apprehension of the essential mechanical principle of its operation, would seem to have been a simple and easy thing, not that the simplicity of such an achievement, as regarded after the fact, in any way predicates the likelihood of its early accomplishment. All through the ages we have waited so long for the simplest things that we have been surprised when they have appeared, and have been slow to appreciate them fully.

The realization of a novel invention is not unlike the catching of a fish, which is a simple enough trick, only that we have to wait, alert and prepared, until the fish comes along; and then the true fisherman's skill is not in getting the nibble, or even a bite that holds, but in landing the fish securely into the net of practical realization. The catching of a fish does not seem to typify the entire operation of successful invention satisfactorily. The patient working out of all the details of adaptation and practical employment, so that the new apparatus shall show decided advantages over all its predecessors, is quite another and a more protractedly labourious work than the first secure grasping of the idea.

In fishing for inventions, each catch is different from all which have been caught before, and after the capture many things remain to be learned, both those which have preceded it and those which will come after it, as one thing always leads to another. Each notable mechanical invention has been essentially a simple one in itself, but the study and development of its relations and adaptations have always employed many keen wits besides that of the so-called inventor.

At first it might be wondered why the plodding and faithful steam or air-driven rock drill should have been interfered with, and how a device so different in some of its essentials could possibly develop any advantages. In the first place, it may be hastily and honestly argued that the new electric air drill is a complicated arrangement as compared with the simple old rock drill. When the thing is looked into this objection becomes a self-evident absurdity, and the new device is a great simplification and effects a great reduction in the size and number of responsible parts. The drill itself has been reduced to its simplest terms and to the fewest parts; all the details of the old drill most complicated, most responsible, most trouble-begetting, most costly of maintenance, have been discarded, with no equivalent devices taking their place. The old drill implied a steam boiler or an air compressor, more or less distant, always entailing great losses in power development, and a costly pipe line to install and maintain and to extend as the work progressed. The new drill is complete in itself, carries everything with it, and its only connection is the electric wire, through which it asks for only one-third to one-fourth of the power formerly required to do the same work. In the actual doing of its legitimate work the new drill asks no odds of the old in any detail of its operation. It strikes a sharper, heavier blow, and more blows per minute. It solves completely the problem of employing the electric current in rock drilling. That it will, therefore, soon knock out the steam or air drill is not to be expected, but that it will be making its way on its merits and that it will be taking the lead in new installations seems natural.

Like all new things, the electric air drill must at first be misunderstood and more or less misrepresented, often with honest intent by those who are not sufficiently or correctly informed. It is well worth investigating as a novelty and for its intrinsic worth.

THE TEMPLE-INGERSOLL

"ELECTRIC-AIR" ROCK DRILL

Electric-Air drill in a mine heading.

On mining, quarry or contract work where electric power is available the ELECTRIC-AIR Drill gives the user all the speed, capacity and endurance of the standard rock drill without the expense of a boiler plant and pipe lines and with **a saving of at least half the power cost.** It can be connected to any power circuit bought at meter rates.

The outfit is ready for work by simply connecting to the power circuit. The only initial investment is for drill outfit and steels. Standard steels and mountings are used. The operator can do his drilling in one-fourth to one-tenth the time required by hand and has his outfit ready for another job, giving him larger capacity at a fraction of the capital investment. Write for Booklet 20 A.

AIR COMPRESSORS **CHANNELERS** **AIR HOISTS**
AIR TOOLS **PNEUMATIC PUMPING SYSTEMS**

INGERSOLL-RAND CO.

CHICAGO BOSTON EL PASO MEXICO LONDON
CLEVELAND PITTSBURGH HOUGHTON LOS ANGELES JOHANNESBURG
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PHILADELPHIA BIRMINGHAM SAN FRANCISCO VANCOUVER MELBOURNE
ST. LOUIS BUTTE SALT LAKE HALIFAX LIMA

V33

Cable Traction for Industrial Transport

THE idea of using cable traction for railway service is an old one. At the time when George Stephenson was endeavouring to secure the introduction of the locomotive on the proposed railway between Liverpool and Manchester the principal rival which he encountered was that which proposed to haul the trains by cable. The success of the competition of locomotives at Rainhill in 1829 settled the status of the locomotive for general railroad service, but the cable was not abandoned for all purposes; it was merely diverted to the special departments of work for which it was peculiarly adapted, and in which it still holds its position by virtue of its fitness and success.

In mine haulage, the cable is found both satisfactory and economical, and in like manner it is employed in manufacturing and industrial establishments for transporting heavy materials from point to point. When properly installed, it forms probably the most economical method yet devised for the purpose, when the low cost of maintenance charges is considered, and for this reason it should always be considered when transport of materials is required and the conditions permit its use.

An important type of cable railway, familiar to many because of its use in large cities for the operation of street railways prior to the introduction of electric traction, is the continuous cable, running at a uniform speed through a closed cycle, the cars being attached by gripping devices to any point on the cable and drawn over the circuit until the grip is released. This system can meet almost any requirements as to grade or curvature, and is well adapted for situations in which the quantity of material to be transported will warrant its use.

In the installation of such a system, designed for continuous operation and intended to be operated at a minimum of cost, the element of durability is of prime importance. High speed is not essential, as the capacity of such an equipment is large, even at slow speeds, and, with a moderate velocity, a workman can step on or off at any point with perfect safety. If, then, the bending stresses on the cable can be kept within moderate limits, its long life is assured. Various methods have been proposed to effect this result, and it is essential that both in the design of guide sheaves on curves and of the grips on the cars the angular deflection of the cable be kept on a curve of large radius, this being the main element in the life of the rope.

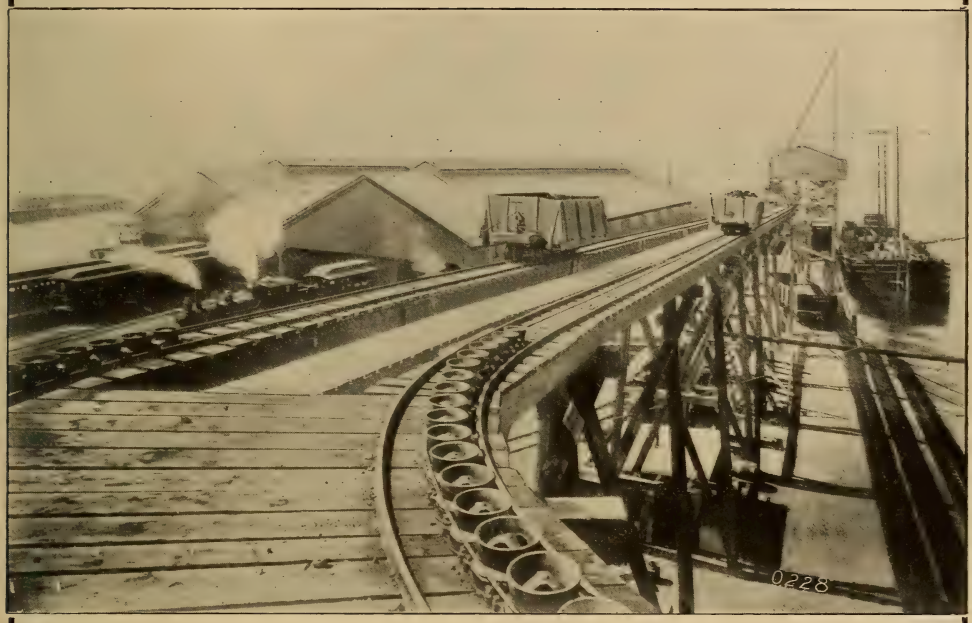
Cable systems of this continuous type are especially adapted for taking material at a wharf and delivering it at any desired point in the storage yard over which the tracks are run. Attendance is required only at the point of loading, as the workman there sets the grip, the unloading being automatically effected at any point, and the empty car returned around the circuit to the starting point.

When such a complete system is not required, a double shuttle plan may be employed, two cars being used, one going out loaded and the other returning empty. For still smaller requirements a single shuttle system is available, a single car being drawn back and forth.

The great point to be considered in the installation of a cable traction system for transport of material is the attainment of the high operative efficiency of which the system is capable. This means that advantage of its continuity of movement be untrammeled, either by interruptions on the part of workmen or because of defective operation or breakdowns. The principal cost of such an equipment lies in the original installation, and it is essential that the system be correctly designed in the first place, and carefully erected as well, the peculiar conditions of each location being taken into account.

"Hunt" Cable Railways

for Handling Coal, Ore, Phosphates, etc.



No. 0228

CABLE RAILWAY OF THE C. W. CLAFLIN CO., BOSTON, MASS.

This cut shows the method of carrying the rope around the curves on a continuous series of pulleys that prevent the short bends in the cable so injurious to its life. It is equivalent to running this cable over a pulley 24 ft. in diameter.

THE cost of handling material with this system is small, as the cars can be carried and dumped automatically at any point wherever desired and returned to the starting place AT THE EXPENSE OF LOADING THE CARS AND THE COST OF POWER TO DRIVE THE CABLE. THE DISTANCE, beyond the initial cost of construction, HAS VERY LITTLE TO DO WITH THE EXPENSE.

We build three types: heavy, double and single shuttle railway, to meet the requirements of plants up to any capacity.

Write and tell us what you wish to accomplish and we will give you the benefit of our thirty-five years' experience in this class of work.

A copy of our Bulletin F-6, containing description and illustrations of a number of the plants which we have installed, will be forwarded on request.

C. W. HUNT CO., West New Brighton, N. Y.
45 Broadway, New York City

Overhead Tramrail in the Machine Shop

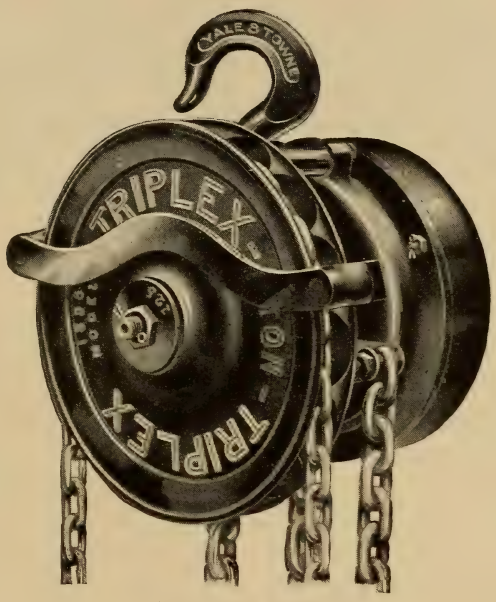
IN nearly every modern machine shop some provision is made for the installing of hoisting and handling machinery as a part of the fundamental equipment of the building. If the design is of the type including a main central bay, with side aisles and galleries, there is generally provided a runway for a powerful traveling crane in the main portion of the building, while jib cranes or small travelers serve the side bays. In some instances two traveling cranes are installed in the central part of the structure, one beneath the other, while less frequently two such machines are placed upon the same runway. Such a liberal provision of overhead transport facilities can be made only when included in the original plan of the building, unless difficult and expensive alterations are permitted; and unless some form of electric driving is adopted for the operation of the tools it is difficult to insure the necessary clear head-room demanded for the best service.

It is generally conceded, however, that overhead transport is the best for a large portion of the handling of work in the shop, and even when it cannot be wholly provided it may be used in some very effective measure by the use of appliances to be had in the market.

Surface transport is most desirable in certain parts of a shop, and nearly every shop is now provided with some sort of industrial track, running through the main aisles of the building and communicating with external parts of the plant. Such track, with proper care and equipment, may be considered almost as a necessity, but its efficiency may be very effectively supplemented by a suitable arrangement of overhead tramrail with chain-block hoists.

Such an arrangement is especially easy of installation in the older portions of existing shops, in which the low head-room, multiplicity of belts and generally cramped situation prevent the full sweep above which newer plans demand. In such a shop there are generally several through passageways in which narrow-gauge tracks may be laid, permitting the bringing in of castings and other rough parts, and providing for the delivery of finished work. Such track only need be carried straight through the building, without turnouts or switches, if there is installed in every cross passage an overhead tramrail, with trolleys from which Triplex blocks or electric hoists are suspended. With such an arrangement the parts brought in on the railway may be lifted and promptly carried overhead directly to the machines by which the work is to be done, while the finished parts may be as readily returned to the surface cars and passed on through the works. Since the machine tools, lathes, shapers, etc., may be placed on the cross passages, they are readily served by the tramrail hoists, and since clear head-room is required only in the passages, the belts from countershafts, etc., offer no interference. There is thus provided a convenient and efficient combination of two of the most valuable transport elements available for shop use, the surface industrial railway and the overhead tramrail and hoist, and both are adapted for use in situations in which traveling cranes can be installed with difficulty.

It has been said of the plant of a great manufacturing establishment that it is rarely designed as a whole, but that it grows with the demands of commerce for its products. This being the case, it is evident that the different parts represent successive stages in shop evolution, and that the older parts need reinforcement with modern appliances to enable them to keep up with the pace set by the newer portions. In no way can such improvement be better made than by the installation of such transport facilities as will save time where it is most generally wasted—between the operations of actual machining.



The Triplex Block

OUR Chain Blocks are made in four kinds and twenty sizes for every hoisting need:

Triplex, the best *hand* hoist; greatest ease, safety and speed. Capacity ½ to 20 tons.

Duplex, for ease and handiness. Capacity ½ to 10 tons.

Differential, the cheapest reliable chain block. Capacity ⅛ to 3 tons.

Y. & T. Electric, the best *power* hoist for rapid work. Capacity 1 to 16 tons.

We have a carefully illustrated catalogue showing them in use under various conditions. Let us send it to you.

The Yale & Towne Mfg. Co.

9 Murray Street, New York

Electric Control for Furnace Hoists

ONE of the essential requirements for the proper operation of blast furnaces is that there shall be a good distribution of material on the furnace bell. To accomplish this the skip delivering the material must always travel at exactly the same speed when rounding the dumping knuckle; this in spite of the fact that the burdens carried vary widely in weight, the range usually being from a 4,000-pound coke load to a 20,000-pound ore load. The problem is further complicated by the very limited amount of head room usually available, which makes it necessary to always stop the skip within a few inches of a predetermined point, in order that the skip may be fully dumped, and, at the same time, may not be wrecked through overtravel.

To economize time, the skip cars are almost invariably run at a high rate of speed. The usual method of reducing the speed of a direct-current motor is by inserting resistance in its armature circuit; but when this is done, the speed-regulating characteristic inherent to such motors is lost, and the speed becomes dependent upon the load which the motor is driving at the time.

To meet the varying conditions of this service, the Cutler-Hammer Manufacturing Company has designed a controlling system comprising five elements:

First—A master switch.

Second—A magnetic switch control.

Third—Limit switch.

Fourth—Automatic speed regulator.

Fifth—Solenoid brake.

The operator, having filled the skip with the proper material, throws over his master controller, thereby releasing the solenoid brake and causing the magnetic switch control to start the motor in the proper direction and to automatically accelerate it to full speed, the rate of acceleration being governed by current relays, which prevent the accelerating current from exceeding a predetermined value. When the skip car reaches a position, say 15 or 20 feet from its dumping point, the limit switch causes the reinsertion of the starting resistance, and at a point some 5 or 6 feet further along, after the motor has been allowed to slow down to a certain extent, a resistance is shunted across its armature, still further reducing its speed. Simultaneously, the automatic speed-regulating device is put into operation. The amount of resistance inserted at the slow-down point is sufficient to reduce the motor speed to that desired when handling the heaviest load. The automatic speed-regulating device, however, if the load be light, automatically inserts a sufficient amount of additional resistance to slow the motor down to a predetermined speed. The design of this automatic speed-regulating device is such that the greater the difference between the speed at which the skip is traveling and the predetermined slow speed, the more rapid its corrective action will be, and as the synchronous speed, so to speak, is approached, the rapidity of correction is decreased, so that the device never overtravels; consequently, there is no "hunting." The skip car, therefore, under the governance of this automatic speed-regulating device, rounds the dumping knuckle at an absolutely constant speed, regardless of the load which it may be carrying. When the car has reached its dumping point, the limit switch, acting upon the magnetic switch control, cuts off the motor current and applies the solenoid brake. Since the motor is, through the action of the automatic speed-regulating device, always operating at exactly the same speed when the solenoid brake is applied, the error in stopping will be very slight indeed, varying only with the coefficient of friction between brake band and wheel.

This device has shown itself successful in practice, enabling the position of the skip to be closely controlled under widely varying load and power conditions.

Manufacturing News

Present Steam-Turbine Development

ONE AND ONE-QUARTER MILLION H. P. MARK PASSED

THAT the steam turbine is not losing ground in its rapid introduction into all classes of power service, is evidenced by the following table, showing the aggregate turbine business of the Westinghouse Machine Company at the beginning of the year, classified according to industries. This table shows a summary of 640,700 kilowatts, or 930,000 B. H. P. This output is distributed among 282 plants (3,298 B. H. P. per plant) and 493 machines, averaging 1,886 B. H. P. per machine.

But in addition to this output listed above, there were at that time under construction at East Pittsburg 148 machines. These bring the grand total of the turbine business of this company up to the gratifying figure of 864,300 kilowatts, or 1,253,000 B. H. P., so that the one and one-quarter-million horse-power mark has been passed in the operation of the Westinghouse Companies alone.

Referring to the above table, it is particularly gratifying to note the rapid advancement in steam railroading, textile mills and mining. Although there are comparatively few railroad electrification plants yet installed, their capacity is large—11,670 kilowatts per plant. In paper and textiles, there are twenty-seven plants, aggregating 20,700 kilowatts, or 767 kilowatts per plant. Nineteen mining properties have adopted turbo-electric drive. Thus, while the most fruitful field for the turbine in the early days of its development was in electric traction and electric lighting work, its field has greatly broadened out into the general industries, until to-day nearly 15 per cent. of the total represents manufactures, as against 34 per cent. electric lighting and 51 per cent. in traction. That this result has been achieved with practically one type of turbine is a creditable reflection upon its fundamental design. An idea of the size to which modern central stations have grown is furnished by the fact that nearly 35 per cent. of the total capacity tested is contained in stations of over 10,000 kilowatt capacity. A decade ago, at the beginning of the turbine business, stations of this size were few and far between. To-day most large cities can boast of at least one, if not several, stations of this capacity.

In this connection, some data on the development of the Parsons type turbine for marine work in Europe are of particular interest. Sir William Matthews, in his recent presidential address before the British Institute of Civil Engineers, cited the following facts:

"In the middle of the present year (1907) there were in service sixty-

SUMMARY OF WESTINGHOUSE TURBINE DEVELOPMENT, INCLUDING ALL PLANTS SHIPPED OR ON ORDER UP TO DEC. 31, 1907

Classification	Plant Capacity Up to 1,000 Kilowatt	Plant Capacity Above 10,000 Kilowatt	Total Number of Plants	Average Capacity of Turbines Kilowatt	Total Capacity Kilowatt
Electric Traction					
Electric railways	18,900	144,500	69	1,975	282,600
*(Railroad electrification)	.....	33,900	4	3,350	46,900
Total	18,900	178,400	73	.....	329,500
Electric Lighting					
Central stations	23,550	45,000	73	1,440	180,100
Isolated plants	3,200	.....	7	400	3,200
Municipal	4,000	.....	11	570	8,700
Total	31,700	45,000	91	.....	192,000
Steam Railroads					
Railroad electrification	.....	33,900	4	3,350	46,900
*(Railroad car shops)	9,200	.....	17	490	15,700
Total	9,200	33,900	21	.....	62,600
Industrial					
Textile mills	8,200	.....	22	595	13,700
Railroad car shops	9,200	.....	17	490	15,700
Cement mills	700	.....	5	1,012	7,100
Iron and steel works	1,000	.....	3	500	5,000
Pulp and paper mills	800	.....	5	778	7,000
Rubber works	900	.....	4	621	4,350
Powder works	1,200	.....	2	400	1,200
Machinery manufacturers	5,400	.....	12	576	15,000
General manufacturers	5,750	.....	11	453	7,250
Total	33,150	.....	81	.....	76,300
Mining and irrigation	8,000	.....	19	686	21,950
U. S. Government	1,750	.....	4	1,225	12,250
Miscellaneous	6,700	.....	14	483	8,700
Grand total	99,250	223,400	282	.....	640,700

* Industries in parentheses, but allowed for in grand total.
Note.—Business uncompleted Dec. 31, 1907: 60 turbines of 153,550 kilowatt; total, leaving shipped or in operation 433 machines, or 487,150 kilowatt, averaging 1,122 kilowatt.

one steamships fitted with Parsons turbines and sixty-five under construction to be furnished with them. The total horse-power of these ships approached 1,400,000. Of this, about 42 per cent. was in merchant vessels and yachts and 58 per cent. in warships. In new ships of the Royal Navy reciprocating engines had given place to turbines."

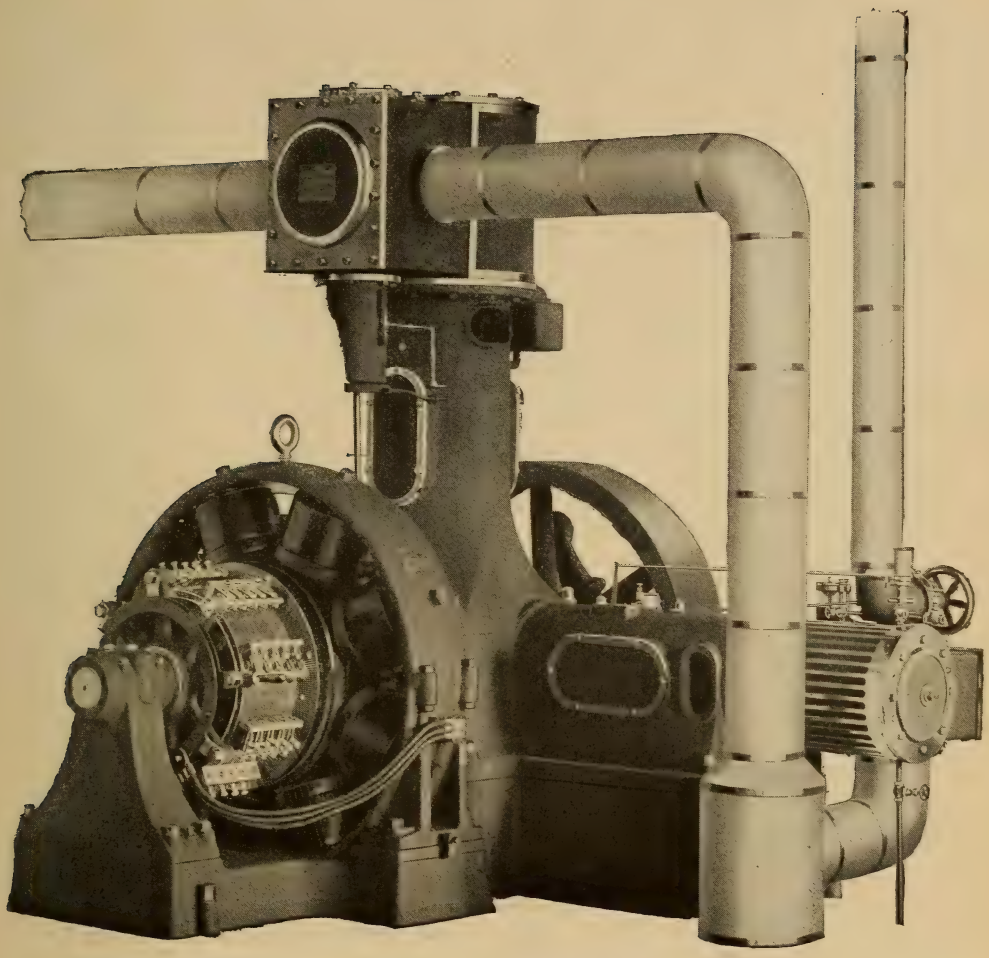
The American-Ball Angle Compound Steam Engine

THE general plan of combining a horizontal and vertical engine operating on the same crank-pin is by no means new, but it has generally been adopted for machines of large size, equipped with Corliss or other four-valve gears. Such engines are in use in the power house of the New York subway, and the value of the arrangement is generally conceded.

Mr. F. H. Ball, the well-known engine designer, with his son, Mr. F. C. Ball, has adapted this arrangement of cylinders to the design of a compound engine of the single-valve type, which possesses a number of advantages, especially with respect to the opportunities which it offers for securing an effective balance.

In the "angle-compound" engine, herewith illustrated, the conditions for perfect balance are brought about by making the low-pressure piston a very light, conically-shaped steel structure of about the same weight as the ordinary cast-iron piston in the high-pressure cylinder. The low-pressure engine is made the vertical engine, because it is thought desirable to have the larger piston rest on the piston rod rather than to drag in a horizontal cylinder.

The high-pressure valve is driven by the usual valve gear and shaft governor, and the low-pressure by an eccentric which is enclosed in an oil-tight casing and connected with



AMERICAN-BALL ANGLE COMPOUND ENGINE

the oil-circulating system of the engine. From this eccentric a rod drives direct to the low-pressure valve stem, which is guided by a crosshead carried in guides, as shown, and this crosshead and guides are also included in the oil-circulating system of the engine. This oil-circulating system is similar to that used on the American-Ball engines, with which engineers are familiar, except that the oil is pumped directly to the gravity storage tank on the low-pressure frame, which is kept constantly overflowing by the supply delivered to it from the pump.

A double stuffing box on the valve stem and bulkheads and stuffing boxes on both piston rods prevent the water drip from mingling with the oil of the circulating system. The water drip from all these stuffing boxes is carried off by concealed piping, so that the engine is never untidy in appearance.

A new departure has been made in this engine in the arrangement of the crosshead and guides, which are of the bored type. It will be noticed that the crosshead is a single piece, without the usual adjusting shoes, while the guides are made adjustable. These guides are carried in bored seats, and a projection from

the back of the guide fits between the supports so as to resist end thrust. One of the guides is secured to the support by screws, and is only adjustable by means of shims; but the other has a pair of screws at each support to provide for delicate adjustments, and the guide is securely held against these adjusting screws by a bolt that locks the adjustment securely when set up.

It is, of course, understood that the crank-pin is double the usual length, and that the connecting-rods are placed side by side on this double-length pin. This completes the general description of this new and interesting engine.

It is evident that the floor space of this engine is very small. Since a horizontal engine carries a vertical engine of the same power, the power for a given floor space is, therefore, doubled. This also reduced the cost of foundation to the same extent, so that practically half the foundation is saved; besides, the perfect balancing of the engine makes the foundation problem such a very simple one that, where concrete floors are used, no further foundation is ordinarily required, thus saving the entire cost of foundation.

For large powers these engines, combined in pairs, with the generator or belt wheel between them, make an exceedingly compact unit. In these combinations the engines are used as double compounds when run non-condensing, or where condensing water is available, as four-cylinder, triple-expansion engines. In the latter case one horizontal engine is the high pressure, the other horizontal the intermediate pressure and the two vertical engines combined are the low pressure, thus giving a large area of low-pressure piston without using any pistons of very large diameter.

The engines are built by the American Engine Company, Bound Brook, N. J., from whom further information concerning them may be obtained.

Large Coal Companies are Heavy Purchasers of Electrical Machinery

AMONG the encouraging signs of the times, from an industrial standpoint, has been repeated purchases of electric generators, motors, transformers, etc., particularly motors, by the leading coal companies. A recent inquiry at the electrical works of Allis-Chalmers Co., which has been especially prominent in supplying this class of trade, reveals the sale of apparatus to the Elkins Coal & Coke Co., Morgantown, W. Va.; Big Coal Co., Pittsburg, Pa.; Berwind-White Coal Mining Co., Windber, Pa.; East Tennessee Coal Co., Jelico, Tenn.; Frick Coal & Coke Co., Pittsburg, Pa.; McKell Coal & Coke Co., Kilsyth, West Va.; United States Coal & Coke Co., Gary, W. Va.; Ellsworth Coal Co., Ellsworth, Pa.; W. J. Rainey Co., Connellsville, Pa.; Merchants Coal Co., Boswell, Pa.; Woodward Iron (& Coal) Co., Woodward, Ala.; Somerset Coal Co., Jennerstown, Pa.; Pittsburg Coal Co., Grindstone, Pa.; Monongahela River Consolidated Coal & Coke Co., Milesville, Pa.; Buffalo & Susquehanna Coal & Coke Co., Du Bois, Pa.; Norfolk & Western R'y Co.'s Coal Mining Department, River Coal Co., National Mining Co.; various subsidiary companies of the United States Steel Corporation and other iron and steel plants, and numerous smaller operators scattered throughout the anthracite and bituminous coal producing sections of Pennsylvania, West Virginia, Ohio, Indiana, Illinois and the South.

Aside from the operation of electric haulage locomotives, which are now very generally used throughout the country, one of the principal uses to which motors have been put in collieries is for connection to ventilating fans, a service for which they offer special advantages. Electric hoists are rapidly coming into favour; motor-driven centrifugal pumps have proven both economical

and convenient, and elevators, conveyors, dumps, etc., can be most effectually operated and controlled when subject to the simple turning of a rheostat handle or switch. Then there are the small self-discharging steel cars, known as "larries," which travel on a net-work of overhead tracks, at the will of the operator—all propelled, directed and dumped by the use of electric current; cranes, grab-buckets, crushing rolls, scrapers, carpullers, brakes and various auxiliary devices which have reduced coal and coke operations to an almost automatic basis. Taken all in all, the field is a very wide one, and it means a constant demand upon manufacturers of electrical apparatus for practically every type of machinery which they build, whether for generating, transforming, driving or electric lighting. As a barometer of financial conditions, this great industry is probably second only to that of iron and steel, and its prophesy for the future is the gratifying activity of the present.

Coal Storage for New York City

IT is a fact perhaps little known that New York City and some of the vessels in its harbour consume at least one-eighth of the country's total output of anthracite coal. The strict regulations against defiling the atmosphere with black smoke make it impossible to use bituminous coal except with smoke-consumers. The adoption of these is not warranted from the standpoint of economy except in cases where the consumption of coal is very great, as in power houses and factories; hence the demand for the cleaner anthracite.

This market in New York means, of course, that the nearby storage facilities must be enormous. The large railway and coal mining companies all have their tidewater plants, where the coal is stored for ultimate delivery in New York. The Philadelphia & Reading, the Central of New Jersey, the Lehigh Valley, the Lackawanna, the Delaware & Hudson—all of the so-called anthracite coal roads—dump their trainloads of coal at these plants every day in the year. Not only along the Hudson River and on the shores of New York Bay, but down the New Jersey coast and in the suburbs several miles inland the "pockets" and the conical, uncovered piles of coal are to be seen from train windows.

Taking in its facilities everywhere, one company, it is estimated, has a storage capacity of 2,000,000 tons. Four hundred and eighty thousand tons can be stored by the Philadelphia & Reading Coal & Iron Company at Abrams, Pa. The Lehigh Valley plant's capacity at Ransom, Pa., in one continuous pile, is put down at 383,000 tons. Three hundred and seventy thousand tons can be kept at South Plainfield, N. J., without the plant being overtaxed. At Abrams the tonnage is divided into eight huge piles, each with a capacity of 60,000 tons. By means of the modern machinery it is possible to stock 14,400 tons in a day of ten hours. The coal can be reloaded into cars at the rate of 10,000 tons a day.

An immense slanting truss with a chain conveyor, constituting what is known as a "trimmer," is a conspicuous feature of an outdoor coal storage plant. By the conveyor coal is delivered, to begin with upon the ground, and then at the ascending apex of the pile. Gradually the mass of coal grows higher and higher, forming a bulky cone against the skyline. The movable trough bottom of the conveyor makes it easy to change the point at which the load is emptied. This discharge point is kept a little in advance of the apex of the cone, so that a gentle fall is effected and breakage is reduced to a minimum. In a reloading conveyor, often running in a tunnel beneath the level of the pile, the coal is carried to the reloading tower. There it is screened before being chuted into the cars for shipment.

The mechanism through which the coal is sent into the reloading conveyor is capable of reaching any part of the entire storage area.

At one time or another, every shipper is apt to experience the embarrassment of having to use box cars to transport his coal. To make this operation easy a "box-car loader" has been invented. The one at Ransom has a capacity of twelve cars an hour. The machine consists of an oscillating cradle. When the car is on the cradle the axis of rotation is straight through the middle of the side doors. The door openings are bulkheaded to a height of 3 feet, and the loading begins. As the coal streams in, the cradle lets one end of the car down, filling that end, and then lets the other end down, to be filled in its turn.

It would seem that the coal would fall back when the loaded end is tilted up; but it does not, owing to the fact that a sharper angle is required to start coal from rest than to keep moving coal that is already in motion.

The screening and resizing of coal that is being taken out of storage is an important feature. Inevitably some breakage, even if it be little, must take place during the coal's passage through the plant. After the small pieces are separated from the other coal, a large percentage of the so-called screenings can be saved by resizing. When this is carried out in a systematic manner, as it is in the modern anthracite storage plant, the resulting economy is not to be despised.

Elaborate provisions have to be made for "melting out" anthracite during cold snaps.

If snow falls and melts, and then the mercury drops below the freezing point, the limit of bad conditions has been reached. The coal, either in a car or on the pile on the ground, becomes a solid mass, which is more like rock than coal. Extra forces of labourers must be employed to attack the frozen mass with picks, and steam must be applied to loosen the great lumps. When New York was in the grip of its worst cold spell this winter the superintendent of one of the big coal docks on the New Jersey shore said that he had to employ just twice as many workmen as ordinarily. Here the cars that come direct from the mines unload their coal into the scows of New York dealers, and a big surplus is also kept in bins under the tracks. The coal in both the cars and in the bins was frozen.

A boiler plant to supply steam for melting purposes solely was built at this dock some time ago. It is used for only a few days each year—that is, when the coal freezes. When that time comes, the steam is sent over the company's docks and yards in pipes. The men stick the pipes down into the coal, and in this way warm the coal into such a condition that it can be moved through chutes. At best, it is very slow work.

Personal

Mr. Philip J. Nash has taken charge of the sales department in Chicago of the Ernst Wiener Company, of New York. Mr. Nash has long been connected with the business of railway specialties, and is both a technical and a practical man. His offices are at 863 Monadnock Building, Chicago.

Mr. Lester G. French has been placed in charge of the editorial department of the American Society of Mechanical Engineers. Mr. French is a graduate of the Massachusetts Institute of Technology, and for a number of years was editor of "Machinery," and recently a publisher of technical books at Brattleboro, Vt.

The Wisconsin Engine Company, Corliss, Wis., manufacturers of Corliss steam engines, gas engines, pumping engines, air and gas compressors, etc., have established a branch office in Atlanta, Ga., with offices in the Candler Building. Mr. Julius M. Dashiell has been appointed sales manager.

THE LATEST CATALOGUES

Transmission

COATES CLIPPER MANUFACTURING COMPANY, Worcester, Mass.—Bulletin No. 21, devoted to the Coates unit-link flexible shaft for the transmission of power. Illustrations are given of numerous applications to machine tools, buffing and polishing outfits, grinding apparatus, sanders and miscellaneous uses. Combinations of electric motors with flexible-shaft transmission are shown, indicating the effective manner in which the tool can be brought to the work by this means.

Lubrication

PITTSBURG GAUGE & SUPPLY CO., Pittsburg, Pa.—Illustrated pamphlet describing the White Star continuous oiling system for power plants. The system includes a storage reservoir from which the lubricant is piped to the bearings and other points to be oiled, together with a drainage system, separating the oil from any water which may have become mixed with it, and delivering it to a filter, which removes dirt and other impurities, the filtered oil being delivered to the elevated reservoir by a steam pump ready for use again. A number of arrangements of piping and filters are shown, together with separating tanks, oil pumps and fittings, enabling the system to be used in a variety of situations.

Pulverizing

LEHIGH CAR, WHEEL & AXLE WORKS, Fullerton, Pa.—Handsomely illustrated pamphlet devoted to a description of the Fuller-Lehigh pulverizer mill, for grinding cement, plaster, fertilizers, ores and refractory materials. The mill is of the ball type, the grinding being effected by the action of chilled balls upon an anvil die or ring, the separation of the finely pulverized material being effected by air currents, so that the machine is a combined pulverizer and air separator. The details of the apparatus are fully shown by a number of effective illustrations, and plans showing the arrangement of the apparatus in actual service are given.

Gas Engines

THE ALAMO MANUFACTURING COMPANY, Hillsdale, Mich.—Bulletin No. 16, a descriptive circular of the Alamo mining hoist, being a geared hoist combined with an Alamo gasoline engine of 25 horse-power. The arrangement of regulating levers and brake is well shown, and the outfit is well designed to be under the complete control of the operator.

THE ALAMO MANUFACTURING COMPANY, Hillsdale, Mich.—Catalogue No. 27, devoted to the Alamo gas, gasoline and distillate engines, for use in factories, farms, mines, railway stations, etc. These engines are of the four-cycle type, and are made in sizes from 3 to 50 horse-power, and the details of construction are fully described and illustrated. Attention may be called to the pan-cooling device, which enables the quantity of cooling water to be reduced to a minimum, also to engines for use with alcohol fuel.

Cranes

THE BALANCED CABLE CRANE COMPANY, New York City.—Catalogue describing the system of overhead cableways, designed and patented by W. F. Brothers, for use in shipbuilding, bridge erection, excavations and general conveying. The overhead cables are extended between shears, which are inclined apart from each other, the tension of the cable being opposed by counterweights, maintaining the system in balance at all times. This system is in use in Palmer's Shipbuilding Works, at Jarrow, England, and was employed in connection with the construction of the Zambesi bridge, the New York subway and other important works.

The Reach of the Rock Drill

THE rock drill was originally devised for the specific purpose of perforating rock, usually for the insertion of explosives, and it would seem that its originators had never a thought of its employment for any other purpose than that of making holes in hard and brittle material. It was far enough from perfect in the beginning and many ingenious ones successively contributed to its improvement and to the securing of the high efficiency ultimately attained.

As happens to men so does it happen also to their instruments and agents. The achieving of valuable results leads invariably to the extension of the field of employment, and the doer of one thing well is before long promoted to the doing of many things often quite different from the first employment. First of all, the rock drill covered all the original requirements of rock drilling, being made in all sizes and with various peculiarities of detail to suit the different kinds of rock and the different conditions of working. Then besides the drilling of round holes in rock in any position and of any size and depth, and often under water for the deepening of navigable channels, it became a channeling machine in quite a different sense. It was arranged to cut channels or thin grooves in rock, and thus provided the working idea, and the means of carrying it out, for an entirely new and in fact a revolutionary system of stone quarrying.

The advantage thus secured and the economy of material and of labor permanently established by the modern system of steam quarrying are not sufficiently known or appreciated. We no longer attack a bed of rock in a careless and haphazard fashion, putting in holes without any semblance of system and then with heavy charges of explosives knocking out shapeless chunks of rock of all conceivable sizes, some of them to be then laboriously shaped to whatever dimensions they might happen to come to, many to be entirely discarded and also vast quantities of material cut away in the shaping of those which could be made available. We work carefully to dimensions in the act of quarrying. Usually there is a level or a vertical face to work to and then the piece to be produced is laid out and is cut to the size and shape required right in its native bed with little material wasted in the finishing and the rock is in perfect shape and condition for other carvings to follow.

Then there is the line of percussion coal-cutting machines, another adaptation and another extension of the employment of the rock drill. These also are of the channeling rather than the boring type, and they are making their own way, so that the proportion of machine-mined coal is constantly on the increase and production is cheapened.

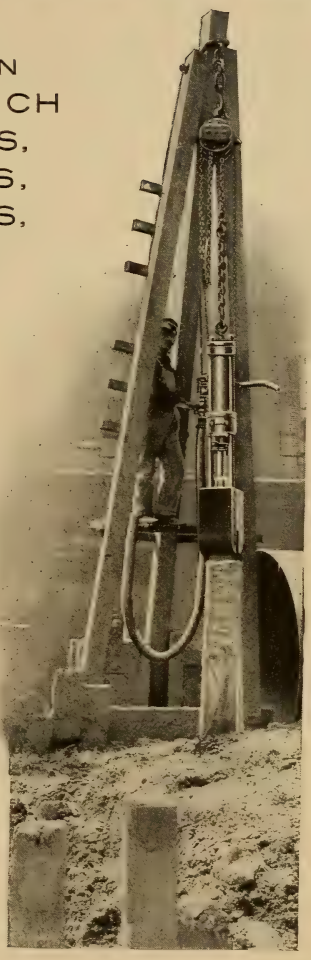
The sheathing pile driver, another direct development of the rock drill, is in a way the simplest adaptation of the percussion principle. It applies force without the intervention of tools. It takes the place of the sledge and the man. It saves only labour, but nowhere, perhaps, has any device a chance to save in such a wholesale fashion. It will shower blows upon the end of a pile with such force and rapidity that it will do in a minute as much as a man would do in an hour, and never stops to rest. It thus by its facility makes a way for itself as few devices have had the opportunity to do, and it is sure of its job with the modern engineer.

And now we come around to a curious development, in that through the pneumatic tool the rock drill comes around to its original employment again. The so-called "hammer drill" which is now in highest favour with miners for "stoping work" is purely and simply a "pneumatic tool," the drill bit being forced constantly against the rock instead of reciprocating as in the "rock drill."

SHEET
PILE DRIVERS

FOR DRIVING PILING IN FOUNDATION AND TRENCH EXCAVATIONS, SHAFTS, RETAINING WALLS, COFFERDAMS, DOCKS, ETC.

THESE machines drive wood piles with no "brooming" of the top, with consequent waste; while steel piling is driven without injury to the tops. The action causes no side strains, thus making tight, uniform joints for the exclusion of sand, mud or water. Where several courses are necessary or spliced piles are required, the upper pile is not forced aside from the lower. This method gives the highest economy of time, labor, power and repairs. One of these pile drivers will easily do the work of 15 to 20 men with hand mauls, while successfully driving piles to a depth which no number of hand mauls could attain.



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V34

The Modern Contractor

NOT so many years ago the term "contractors' machinery" was supposed to refer to appliances of the roughest and crudest character. An occasional portable steam boiler mounted on skids and capable of being hauled from place to place formed the basis of his power plant, while the machinery accompanying it included some simple hoisting engines and winches, rock drills, pumps, and the like, all being considered satisfactory if it worked at all, the questions of efficiency and convenience being altogether secondary.

To-day the contractor is an engineer to as full a degree as his fellow worker in the shop or the power plant. He is familiar with steam, compressed air and electricity, and uses each as occasion demands. Tools, hoists, engines, pumps, all must be properly designed and built to enable him to cope successfully with the undertakings which are placed in his hands, and the term "contractor's machinery" now means a powerful and effective equipment of the best modern class, its especial feature, apart from its adaptability to the work it is to perform, being in its practicability for transport from place to place, as it may be required upon successive jobs.

Machinery intended for contractors' use should be designed with reference to the fact that it is practically certain to be exposed to weather, to rough handling, and to more severe service than in-door machinery of the same nominal capacity. This means that the parts must be heavy, and the design simple. Such machines are often required to be operated for months at a time almost continuously at great distances from repair shops, and at points which cannot readily be reached if heavy spare parts are urgently required. Any repairs or adjustments which may be needed must be made by the engineer in charge, with the aid of the facilities which are actually at hand, otherwise there may occur serious delays, involving far more in cost and consequences than the necessary first expense required to secure freedom from such defects.

Steam engines intended for contractors' use, either independently or in connection with winches or hoisting machinery, should have simple valve gear, and few working parts. Greater massiveness is needed for such machines than for engines which are secured to solid foundations, since the supports are often inadequate, and the stresses upon shafts, bearings, and connections are often excessive and unequal. Stiffness, rather than strength, should be the main characteristic, and if proper provision is made for stiffness the ability to resist the working stresses will be included.

Electric current is often available for this service, and electrically operated hoists are now designed for contractors' use in such a manner as to render the severe requirements to be most successfully met. In such machines it will not do to take a design originally intended for steam power and merely replace the steam engine with an electric motor; the whole machine should be re-designed both with regard to its service and its motive power.

These considerations hold good with all machinery intended for the use of the contractor, including not only the actual machines themselves, but the appliances with which they are used. Industrial railways, with their steam or electric locomotives, come within this category, while such details as hoisting rope, transmission cables, gearing, and connections of all kinds should be made for service of the most exacting kind, a service which includes exposure to weather, irregular and excessive stresses, ill-treatment from unskilled labor and absence of shop repair facilities, and a service which demands, above all things, unfailing reliability and certainty in its action.

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Below is shown some of the machinery we are building for contractors' work. All goods built in our own shops. A copy of Bulletin F. I. describing each type in detail, will be sent on request.

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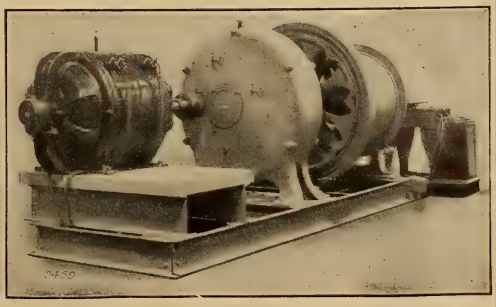
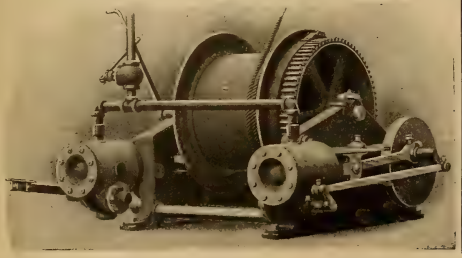
ELECTRIC HOISTING ENGINES



STEAM HOISTING ENGINES



Trolleys and Transport

IN the installation of overhead tramrail for use in connection with chain blocks for the transport of material in the shop even such a simple element as the trolley from which the chain block is suspended, and by means of which the load is carried along the rail, demands skill in design and experience in manufacture. When the older forms of chain block first came into use in the shop such a thing as a trolley was not an article of manufacture at all, nor was there any systematized arrangement of tramrail adapted for the service. The rail was made of flat bar iron, hung from home-made brackets or suspension pieces, the curves, when there were any, being shaped in the smith shop and the whole laid out in a rather rough and amateurish fashion.

The trolleys themselves were as varied in design as there were shops in which they were used, and the controlling elements in the construction of this part of the equipment were usually to be found in the constructive limitations of the particular establishment where it was to be used. In some cases the body of the trolley was cut from plate metal, and in other instances a piece of flat bar iron was bent into a yoke and fitted with a loop or clevis, from which the chain block was suspended, and with fixed pins upon which the trolley wheels were mounted.

With the development of the manufacture of transport appliances into a specialized department of machine construction the trolley naturally received attention and the results of experience and a study of the conditions of operation have become crystallized into certain standard types which have survived the ordeal of severe shop service. These various forms have become standard articles of manufacture, which means that, while they must necessarily be better adapted for the duty they are called upon to perform, they actually cost materially less than the crude contrivances which they have superseded.

It was soon found that the flat-bar tramrail could be advantageously replaced by the commercial steel I-beam, this furnishing a double bearing on the upper sides of its lower flange for the trolley wheels. The stresses were thus centralized, while the trackway was of a form which did not accumulate dirt and which was readily accessible.

With this modification in the rail there became possible the four-wheeled trolley, admitting the introduction of equalizing connections between the two sides, and also permitting the construction of double bearings for the wheels. An important point thus secured is the provision of axles fixed in the wheels and running in bearings, a device as superior to the loose wheel as a pulley with journal bearings is better than the ordinary loose pulley on a shaft. It is also practicable to fit such trolleys with roller-bearings for their wheels, the resistance being thus reduced to a minimum, and the wear also eliminated to a great degree.

In some cases a geared trolley is desired, thus enabling the load to be moved along the rail by the use of a hand chain.

With such a geared trolley and a modern hand hoist of high efficiency a combination is effected which can be used either with tram rail or upon a light crane to form a hoisting equipment of great convenience and efficiency, second only to similar devices fitted with electric power.

In some instances it has been found advantageous to use the combination of overhead tramrail, trolley, and chain block in outdoor work, such as the mixing of concrete, and the like, the rail being carried upon temporary trestles, and the material being brought in buckets, enabling the predetermined proportions of sand, gravel, and cement to be measured while the material is being transported.

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